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Vol. 37 August 1945 No. 8

Restoring Pipeline Capacity at Wichita, Kansas

By M. E. Rogers

Former Asst. Director of Service and Engr. of Water Supply, Wichita, Kan.

Presented on Apr. 12, 1945, at the Wichita Engineers' Club, Wichita, Kan.

THIS account covers four principal items: (1) the rapid loss of hydraulic capacity of a 34-mi. supply line because of the growth of *Crenothrix;* (2) the treatment of the well water with doses of chlorine sufficient to prevent further growth of *Crenothrix;* (3) the special methods developed for restoring the capacity of the line; and (4) the use of mobile radio equipment to expedite the cleaning operations.

Wichita constructed and placed in operation, in September 1940, a complete new water supply system, comprising 25 wells located in Harvey County; 34 mi. of cement-lined, centrifugal cast-iron pipe, varying in size from 14 to 48 in.; a water treatment and filtration plant in Wichita; and a 4-mil.gal. reservoir. The system also includes auxiliary structures such as power lines and communication and control circuits.

The nominal designed capacity of the entire works is 30 mgd. The wells are directly controlled from a central control station located in the well field and remotely supervised and controlled from the filtration plant in Wichita. Each well discharges into a 14-in. header, which in turn delivers into the principal transmission line, varying in size from 20 in. at its upper end to 48 in. at the lower end of the well field, and on into Wichita.

When the permanent supply wells were drilled in 1939 they were found to contain a considerable amount of iron which, it was felt, would produce undesirable effects in the distribution system. It was necessary, therefore, to construct a 30-mgd. filter plant to remove the objectionable iron as well as small amounts of manganese. In addition to removing iron, the plant is capable of further softening the water, resulting in a finished water having very desirable characteristics of softness, taste and appearance.

As originally designed and constructed, the Wichita system was considered adequate to serve the normal

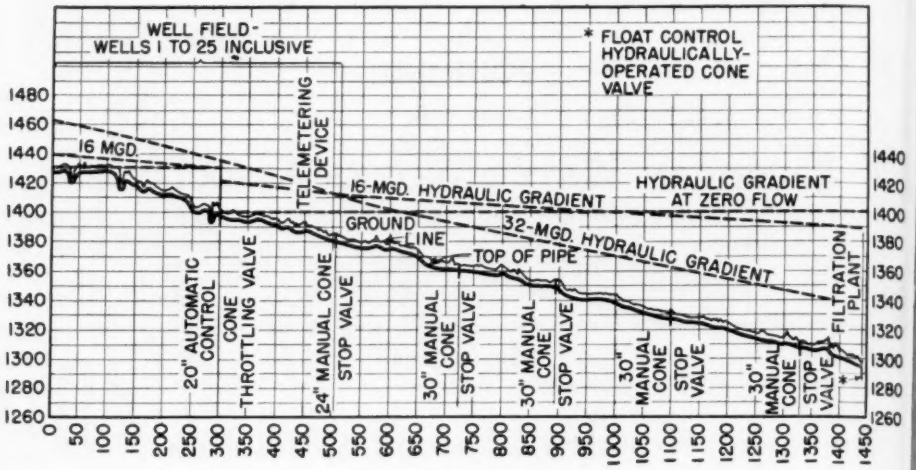

FIG. 1. Profile of Pipeline—Chaining in 100-ft. Sections

population growth of the city up to 200,000 persons, which, it was estimated, would be reached by the year 1960. Because of the large concentration of war industries in the city, the water supply facilities were called upon for maximum production soon after being placed in service. For example, the annual consumption of water in 1940 was about 3,800 mil.gal. During 1944 the annual consumption approached 6,900 mil.gal., with peak days of 26.1 mil.gal. These peaks were held down considerably by restrictions placed on the use of water for lawn sprinkling and by the fact that it was impossible under wartime manpower and material restrictions to serve adequately the new housing developments.

Loss of Transmission Line Capacity

Between 1940 and the summer of 1942, the carrying capacity of the 42- and 48-in. transmission mains had very materially decreased. By June 1943, the capacity had dropped from an initial 30 to a low of 20.4 mgd.—a reduction of about one-third in less than three years of service.

It had been observed during periods of sudden increase in flow or at times of surges within the line that vast quantities of a reddish substance in suspension were flushed out of the line and deposited in the settling basins and on the sand filters. This material was known to consist primarily of iron-depositing bacteria. At first this bacterial growth was studied only as a curiosity and pilot plant tests were made to determine the requirements for its life processes and methods of controlling its growth, since ample capacity was available over and above the requirements then current.

These iron-depositing bacteria, the most common type of which is *Crenothrix*, were found to flourish in the absence of light and oxygen, and to require iron in solution with carbon dioxide for survival.

In June 1942 the interior of the 48-in. main was inspected and observations made indicated that the bacteria

had attached themselves to the cement lining of the pipe to a depth of $\frac{3}{8}$ to $\frac{1}{2}$ in. The actual thickness of the deposit could not account for the tremendous loss in carrying capacity. However, the loss in effective area, coupled with the exaggerated, rippled surface contour of the deposit, which caused great local turbulence about the periphery, seemed to account for the loss in capacity.

In appearance and composition, this accumulation may be described as a slime, consisting of iron oxide deposited by the dead bacteria which were held together by a matrix of live thread-like organisms. The deposit was brick-red in color and could easily be wiped off the seal-coated cement lining of the pipe with the hand. Chemical analyses of the fresh deposit indicated that it contained about 93.5 per cent of water. Further analyses on a dry basis gave the following results:

	%
Insoluble matter, including SiO	0.2
Loss on Ignition	17.9
Fe_2O_3	74.2
$CaCO_3$	5.8
Unaccounted for (probably water of crystallization)	1.9
	100.0

Control of Bacterial Slimes

There are very few instances on record in which the character of the growth which restricted the pipe carrying capacity was identical in nature with that in the Wichita system. Where similar growths occurred in other systems there was, in many cases, sufficient pressure available to flush out the lines and dislodge the organisms by raising the flow to scouring velocities. In Wichita the well pumps at the upper end of the line are not designed to furnish pressures above that necessary to supply maximum demands under approximate gravity flow conditions. It was not practical to flush the main for control and removal of the organisms.

Chemical means seemed to be the proper method of attack, and various technics to achieve this purpose were studied. It seemed obvious that if the source of food could be taken away from the organism it could not exist; therefore, a search was instituted for a method of removing the iron and/or the carbon dioxide from the water before it entered the supply main. One effective and simple means would be the use of a treatment plant such as is now installed at the lower end of the pipeline in Wichita. But, since the Wichita system contains 25 widely scattered wells, it would be a financial impossibility, to say the least, to provide 25 separate treatment units at the wells. Also, where chemical precipitation and neutralization methods are employed, there remain precipitates to be disposed of, as it is not desirable to allow these precipitates to deposit and accumulate in the transmission line.

Gaseous chlorine can be used to kill practically all forms of bacteria and plant life if it can be applied in sufficiently heavy doses and over continued periods of time. With this in mind, closely controlled dosages of chlorine were fed into the pilot plant setups to determine the minimum dosages that would inhibit the growth of the bacteria. From the results of these tests, it became evident that a dosage in excess of 1 ppm. of chlorine would not only prevent the growth from developing but would tend to oxidize and burn out the organic material in the accumulated deposit, causing it to shrink in thickness and possibly to slough.

About the beginning of 1943, the application of chlorine to the well discharge lines was begun on an experimental basis on those wells containing the greatest amounts of iron.

Although the first methods of chlorine feed and its control were crude and erratic, we were encouraged by the fact that during the period from July 1942 to July 1943 the hydraulic coefficient (Hazen-Williams formula) for the 48-in. line had risen from 83 to 86. This indicated that, although attempts to remove the accumulation in the line were unsuccessful, its further development had been inhibited. During June 1943, a commercial chlorinator was leased from another city and installed. Although manually operated to discharge into the transmission line under pressure, it provided a means of feeding higher dosages of chlorine and proved to be a more reliable form of administering doses. This method of operation was continued until February 1944, when additional equipment was secured and heavy dosages of chlorine were applied in an attempt to dislodge some of the accumulation. During this time, continuous gradual improvement in line carrying capacities was noted, but the amount of recovery was not sufficient to meet the requirements during the summer of 1944.

A permanent chlorinating building, with facilities for handling chlorine in ton containers and capable of injecting up to 1,000 lb. per 24 hours against pipeline pressures, was placed in service in July 1944. Since that time a uniform rate of feed of about 3 ppm. of chlorine has been maintained. The rate of feed at the upper end of the pipe carries through the line and leaves a residual of between 0.4 and 0.5 ppm.

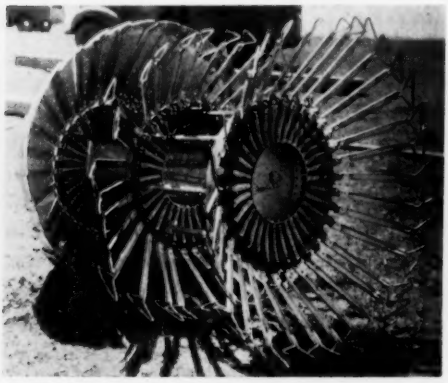

FIG. 2. Cleaning Machine, Showing Special Features of Construction

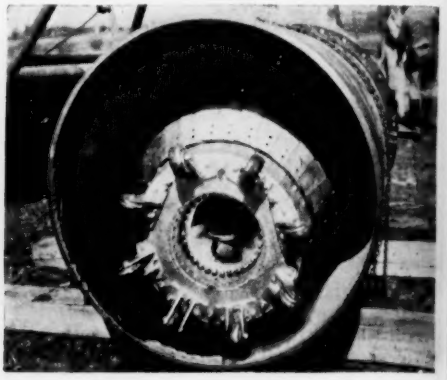

FIG. 3. Machine Installed in Nipple, Looking Toward Forward End of Machine

At the plant, just ahead of the filters, ammonia is introduced to convert the remaining free chlorine to chloramines.

The chlorinating equipment as permanently installed was specially designed to inject the solution against varying pipeline pressures. This was accomplished by taking the solution discharge from a standard chlorinator and applying it to the suction side of a hard rubber centrifugal pump whose capacity was sufficient to inject the maximum solution output of the chlorinator against maximum main pressures. When operating under conditions below maximum output, the additional solution requirements of the pump are

made up from a clear water sump, whose water level is float controlled. This feature allows the chlorinator to discharge under constant conditions and eliminates the radical effect of fluctuating main pressures usually encountered. Ton containers are connected in parallel on duplicate dial scales, reading up to 2,000 lb. of chlorine directly, the weight of cylinder having previously been set off on the tare beam. No computations are necessary to determine the amount fed during any previous period.

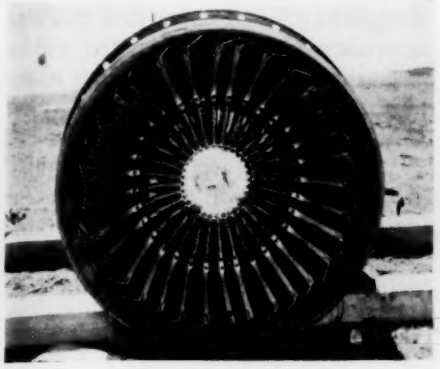

FIG. 4. Rear of Machine Installed in Pipe Nipple

Removal of Pipeline Deposit

It is apparent that, although a substantial and continuous gain in pipeline carrying capacity had been accomplished during the period since the beginning of chlorine application, the process was too slow to provide adequate water supply during the peak summer months for the next several years. Mechanical cleaning of the line to remove the accumulated deposits was necessary to restore the line and system to its full productive capacity.

Although cleaning pipelines by mechanical means has been practiced for years, very little information or experience was available on cast-iron, cement-lined, seal-coated pipe. Generally the need for cleaning occurs on lines which are not protected on the interior against corrosion and the principal restriction occurs either in the form of tuberculation or of calcium carbonate scale where unstablized lime-treated water is conveyed by the system. The usual types of cleaning machines would be too rough on the cement lining. Therefore a special design was required to protect the cement lining.

A further complication was introduced by the fact that there existed restrictions at intervals along the pipeline in the form of cone-type isolating valves. At these valves the 48-in. line is reduced to 30-in. diameter by standard eccentric reducer fittings before and after the valve, and the valve itself has a nominal 30-in. diameter port (Fig. 1).

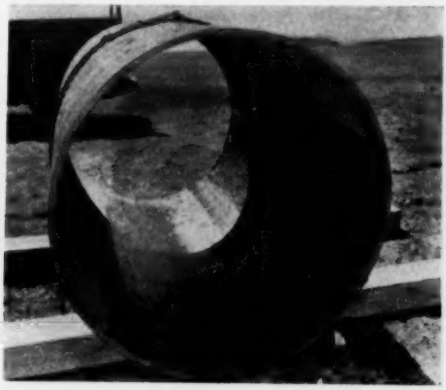

FIG. 5. Nipple Removed From Pipeline—Much of Slime Growth Has Been Removed by Local Surging of Water During Shutdown Operations

A functional specification was prepared on the basis that the successful bidder design and furnish cleaning equipment, as well as supervision, and with the prime requisite that the machine be able to negotiate the restrictions offered by the isolating valves

and that the cement lining be protected. The successful bidder was to furnish bond against damage to the line and covering successful performance of the work and to guarantee to restore the carrying capacity of the 42- and 48-in. lines to a minimum Hazen-Williams coefficient of 130 overall.

The cleaning equipment contract was awarded to the National Water Main Cleaning Co. in October 1944 (Figs. 2, 3, 4 and 5). Difficulties in securing equipment and materials for cutting into the line delayed construction until March 1945.

Cleaning the 42- and 48-in. Lines

The contractor devised and constructed a novel type cleaning machine consisting of a circular piston formed of laminated steel leaves, overlapping so that they could successfully expand and contract as the pipe diameter varied in traversing the valves and bends. This piston was followed by a double ring of wiper arms supported near the center on hinges. That part of the wiper in contact with the pipe wall consisted of a $\frac{5}{16}$-in. rod about 5 in. long and bent to conform to the exact circumference of the pipe throughout its area of contact. These wiper elements looked very much like the handle on a "baled hay hook" and were installed at a slight transverse angle so that they would nest with each other on being compressed and also would approach minor obstructions, such as joints, at a slight angle, thus eliminating chatter and the tendency to catch or chip the lining. Both the leaves on the driving piston and the individual arms supporting the wipers were spring loaded in such a manner that uniform pressure was exerted throughout the pipe circumference, regardless of the internal diameter. The final adjustments of spring tension were made in the field when the machine was inserted into the line.

At the point of entry and exit of the machine a 6 ft. 6-in. nipple was cut into the line and Dresser-type couplings were used to effect line closures both temporarily and permanently. The cuts into the line were made by an A. P. Smith, air-driven cutting machine which proved to be a great saver in manpower and reduced the time of system shut-down to the absolute minimum during the operations (Fig. 6). At the lower end of the 48-in. line a 16-in. blowoff and valve in a concrete pit were permanently installed with a 30-in. discharge into an existing 48-in. drain line leading into the Big Arkansas River some 800 ft. distant.

When cleaning was started, the pipeline was shut down and the adjacent section of pipe was dewatered from the plant end in Wichita. The Dresser couplings were removed and the pipe nipple lifted out, the machine pulled into the nipple by means of a winch line, the machine and nipple lowered back in place, the couplings replaced and bolted up. Then water pressure was built up in the line behind the machine.

So that continuous control over operations might be had with the minimum of lost time and the maximum of safety, two-way radio communication was installed. The representative of the contractor followed the machine in the pipeline and, by means of a "handie-talkie," maintained continuous contact with the city's representative who was stationed near the center of operations with another "handie-talkie." A two-way radio-equipped truck followed the city's representative. In cleaning the 42-in. line, a second radio-equipped truck was located near the upper con-

trol valve at Station 299 (see Fig. 7) to regulate the amount of water flowing through the 42-in. line and thus the speed of travel of the pipe-cleaning machine. In this case the lower end of the 42-in. line was left open and the 48-in. line below that point was valved off so that all wasted water and scrapings from the pipe walls were discharged into a tight sheeted pit and carried away by local surface drainage. A bulkhead was installed in the excavation, so as not to impede the flow of water leaving the pipe at this point but to stop effectively the cleaning machine and prevent its coming out into the opening. Such an occurrence would cause a tremendous and sudden drop in pressure in the line upstream and possible damage to the line due to the vacuum created.

In cleaning the 48-in. line, the procedures were very similar to those employed on the 42-in. line, with the exception that the flow through the line was controlled from intermittent blowoffs at various points along the line below the cleaning machine and at the plant at the lower end of the line. The radios were used, as before, with the exception that one radio car was stationed at the blowoff immediately below the section being traversed by the cleaning machine. The city's representative with the "handie-talkie" and the other radio-equipped truck were stationed nearby on the public road. Also carried was a telephone set which was connected into the land line communication circuits to maintain instant contact with the filter plant in Wichita and also to control the operation of the well pumps at the upper end of the line.

The detailed procedure was as follows: The system was shut down, the sectionalizing valve immediately above the cut at the upper end of the 48-in. line at Station 508 was closed and the pipeline was dewatered sufficiently to allow removing the upper pipe nipple and keep the excavation dry. Then the machine was positioned in the pipe nipple and recoupled into the line. The upstream sectionalizing valve at Station 508 was then opened gradually and the dewatered portion of the line allowed to fill up, air being drained off through air-relief valves permanently provided for that purpose. Well pumps were turned on as needed and the plant inlet valve at the lower end of the 48-in. line was opened gradually until the machine began to move. This flow was gradually increased by manipulating well pumps and opening the lower valve until the desired cleaning speed was obtained. As soon as dirty water was evident at the blowoff immediately below the section being traversed by the cleaning machine, this blowoff was opened to full position,

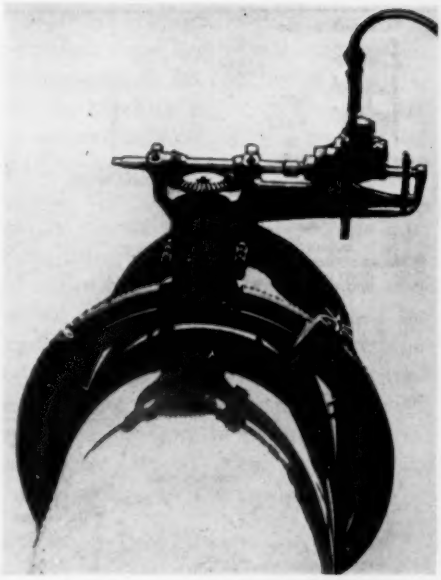

FIG. 6. Pipe-Cutting Machine in Place

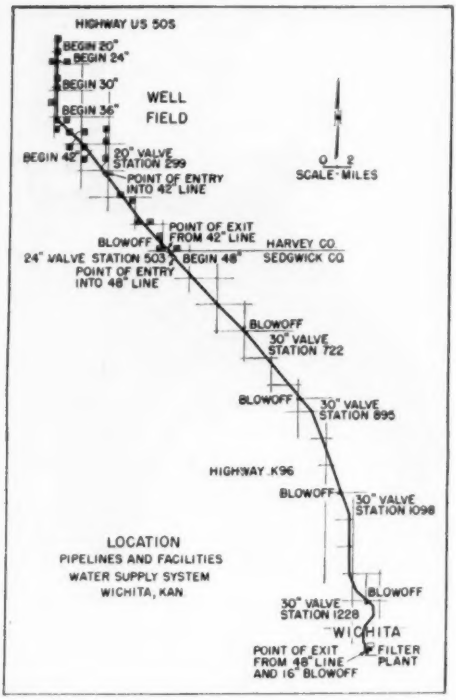

FIGURE 7

with the purpose of discharging as much of the debris as possible ahead of the machine in order to lighten the load on the lower end of the pipeline. It was necessary to prevent piling up of the material ahead of the machine, since after a period of time flushing water approximated the consistency of tomato catsup. As soon as the machine passed one open blowoff, this blowoff was closed and the radio car and operator immediately proceeded to the next blowoff. The valve at the filter plant was opened or closed to maintain uniform pressures upstream above the machine during the manipulation of the local blowoffs. These upstream pressures were transmitted electrically and recorded on a chart at the plant for the information of the operator at that point.

This process was repeated as the machine traversed each 4-mi. section between blowoffs and until the machine passed the blowoff just ahead of the last sectionalizing valve at pipeline Station 1228. Up to this time, all of the water had been going through the filter plant in normal fashion and was being used to supply the city. Dirty water now began to appear at the plant, so the lower end flow control was transferred to the 16-in. blowoff and the entry valve into the plant was closed. While the machine was traversing that section of the pipeline between the last sectionalizing valve at Station 1228 and the filter plant, this sectionalizing valve was slowly being closed. A point was reached in the operation at which the column of water behind the machine plus the gradient of the pipeline was sufficient to drive the machine by its own momentum. When this point was reached, as evidenced by air being drawn into the line at the vacuum breakers on the downstream side of the sectionalizing valve at Station 1228, this valve was completely closed and the well pumps in the field shut down. The machine was then allowed to continue on down the pipeline, its progress becoming progressively slower as head was lost until the machine's driving piston passed the opening into the 16-in. blowoff. At this point the machine stopped dead and the blowoff was opened wide in order to complete the dewatering of the section of pipeline below Station 1228. When dewatering was complete, the removable section of pipe was rolled aside on a railroad iron track provided for that purpose in the pit and the machine was pulled out of the hole and set aside, using the winch line of a truck. An examination was made by walking upstream through

the cleaned portion of the pipeline to determine the effectiveness of the operation. Observation indicated that substantially all of the deposit had been wiped off down to the asphalt seal coat over the cement lining and that the seal coat and cement lining both were intact and in perfect condition. The removable pipe section was then rolled back into place, the Dresser sleeves replaced and the upstream valve at Station 1228 slowly opened to allow the lower end of the pipeline to fill up and the air to be exhausted.

On the 42-in. line, 20,148 ft. were cleaned in four hours and twenty minutes elapsed time, from the time the machine began to move until it reached the outlet end of the section. The machine attained traveling speeds of about 140 fpm. A flow of 20 mgd. was required to drive the machine at maximum speed in the line.

The 92,343 ft. of 48-in. line were cleaned in twelve hours' actual working time. A peak flow of 25 mgd. was required to drive the machine at an average speed of 133 fpm. Approximately 30 per cent of the water passed the machine and was available for flushing. The longest shut-down of the entire system occurred during installation of the 16-in. blowoff and valve near the plant, because no provision was made in the original construction for dewatering the lower end of the 48-in. line and water had to be drained through the first cut made by the pipe-cutting machine. In this case the plant was out of service for sixteen hours continuously during which time water was provided from reservoir storage at the plant and from old wells of the privately-owned Wichita Water Co., which are maintained for emergency use.

As indicated, the cleaning of the 42- and 48-in. lines was two distinct and separate operations. However, each operation, once begun, was carried on continuously to its conclusion; that is, once the machine began to move it was not allowed to stop. In the case of the 42-in. pipe, pressure was applied against the machine upstream with gravity discharge from the lower end of the line. In cleaning the 48-in. line the entire line was under pressure and control over speed was maintained by bleeding water out below the machine and at the plant. The machine traversed the cone valve restrictions with surprising ease, it being necessary to listen carefully at these locations to detect passage of the equipment.

Results

On the day following cleaning of the 48-in. line, flow tests were run on the 42- and 48-in. cleaned sections at various rates of flow. These tests were conducted by observing flows through the 48 × 22-in. Venturi meter at the inlet to the plant. Pressure readings, with reference to the pipe center-line, were taken on the upstream side of the Venturi meter; at an air-release valve at Station 515 +, just upstream from the entry opening for the machine at the upper end of the 48-in. line; on the downstream side of the sectionalizing valve at Station 506; and on the downstream side of the control valve at Station 299 at the upper end of the 42-in. line just ahead of the point of entry for the cleaning machine in that section of line.

The details of these observations at various rates of flow are shown in the accompanying tabulation. Tests using the same points of observation on March 19, just prior to beginning cleaning operations, indicated the Hazen-Williams value of C to be very nearly 110 for both the 42- and 48-in.

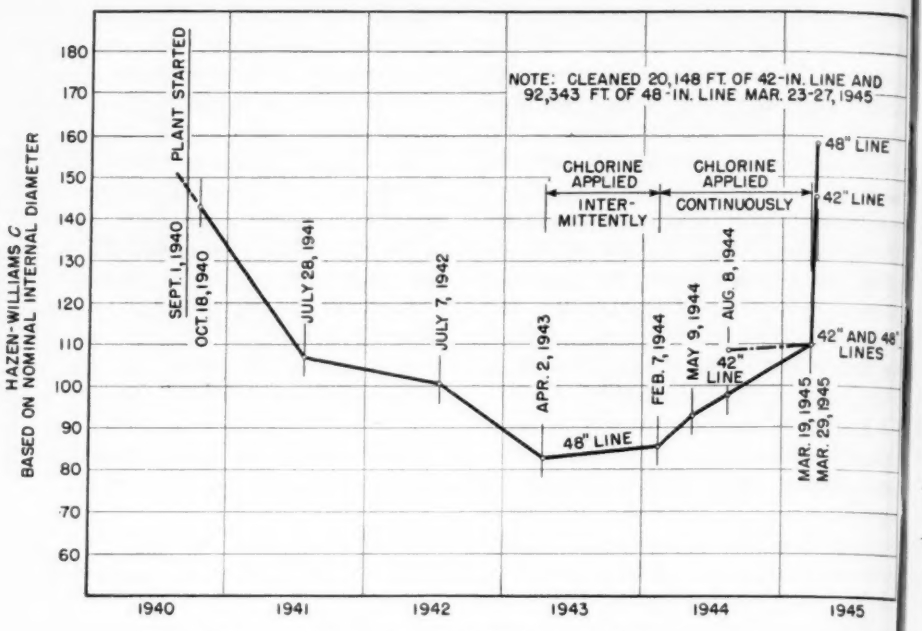

FIG. 8. Changes in Flow Coefficients—42-in. and 48-in. Pipelines

pipe sections (see Fig. 8). The acceptance tests after the cleaning operation indicated values of C to be 143 and 158, respectively, for the 42- and 48-in. lines.

The value of C, particularly for the 48-in. line, seemed unusually high and, in order to satisfy ourselves as to its accuracy, the coefficients were recomputed from data obtained in additional tests run on March 30 at several rates of flow. The average of six different runs on the 48-in. line on March 29 and 30 gave the value of C as 158. This value was computed on the basis of the 48-in. nominal internal diameter of the pipe. Actually there is some variation from the nominal 48-in. internal diameter, since the pipeline was designed and fabricated using the new American Standards Association's specifications for cast-iron pipe (A.S.A. A21.1–1939), which allows the pipe wall thickness under properly controlled manufacturing conditions to be varied in accordance with external loads and internal pressures. In Wichita's case the walls of the centrifugal cast-iron pipe as manufactured by the American Cast Iron Pipe Co., vary from a minimum of 0.74 in. to a maximum of 1.05 in. To this thickness of metal must be added approximately $\frac{5}{32}$ in. for cement lining, which gives a weighted average of 48.70 in. for the internal diameter of the entire length of 48-in. line. The coefficient, as calculated for the 48-in. line and corrected for the actual diameter, then becomes about 153, which is at least as good as, if not better than, the coefficient obtained just after the pipeline was installed. In all these tests gages used were calibrated with a dead weight tester before and after taking observations to eliminate errors from this source.

Flow Coefficients (Hazen-Williams)
48-in. Pipe

Date	Slope (S)	$S^{0.54}$	Hydr. Radius, *ft.* (R)	$R^{0.63}$	Quantity Discharged, *mgd.* (Q)	Velocity, *fps.* (V)	Coefficient (C)
Oct. 18, 1940	0.000356	0.0136	1	1	20.8	2.56	143*
July 21, 1941	0.000563	0.0175	1	1	20.1	2.47	107
July 7, 1942	0.000615	0.0183	1	1	19.7	2.43	101
Apr. 2, 1943	0.00088	0.0222	1	1	19.7	2.43	83
Feb. 7, 1944	0.000956	0.0232	1	1	21.4	2.63	86
May 9, 1944	0.000804	0.0212	1	1	20.25	2.49	93
Aug. 8, 1944	0.000851	0.0219	1	1	23.0	2.83	98
Mar. 19, 1945	0.000487	0.0162	1	1	19.1	2.35	110
Mar. 29, 1945	0.000265	0.0116	1	1	19.7	2.92	159
Mar. 29, 1945	0.000574	0.0177	1	1	29.6	3.65	157*
Mar. 30, 1945	0.000271	0.0118	1	1	20.1	2.47	158
Mar. 30, 1945	0.000418	0.0148	1	1	25.2	3.11	159
Mar. 31, 1945	0.000211	0.0103	1	1	16.7	2.06	153*
42-in. Pipe							
Aug. 8, 1944			0.875	0.919			109*
Mar. 19, 1945	0.000813	0.0213	0.875	0.919	17.7	2.84	110
Mar. 29, 1945	0.000508	0.0166	0.875	0.919	18.3	2.93	146

Note: 42-in. main cleaned on Mar. 23, 1945
48-in. main cleaned on Mar. 27, 1945
Chlorine introduced at upper end of 42-in. pipe intermittently and in varying amounts after October 1942. Systematic chlorination begun in heavy doses on May 1, 1943.
* Computed using data obtained from recording pressure charts.

In order to determine maximum flow line capacity, on March 29, immediately after cleaning, 23 wells were placed in operation to provide a theoretical flow at the rate of 30.2 mgd. The actual rate of flow, as measured at the plant Venturi meter, was 29.6 mgd. Theoretically, had all wells been operated, they would have sufficiently raised the pressure at the upper end to furnish a flow of more than 31 mgd.

Acknowledgments

The National Water Main Cleaning Co. designed and furnished the cleaning machine used. Special credit is due to J. A. Frank of that organization for his development of the special equipment and methods required for these operations. Grateful acknowledgment is made to the Kansas Gas and Electric Co. of Wichita for use of their radio-equipped trucks, to the Army Air Forces for their co-operation, and to the Federal Communications Commission for their issuance of emergency permission to use radio equipment. Had the radio control not been available, much lost time and expense, as well as great uncertainty in supervising operations would have occurred. The consulting engineering firm of Black and Veatch, who originally designed the Wichita system, assisted with the preparation of the cleaning specifications and contract documents. All field labor and materials were furnished by the Wichita Division of Water Supply.

A Postwar Program for Jackson, Mississippi

By E. L. Filby

Engr., Black & Veatch, Kansas City, Mo.

A contribution to the Journal

JACKSON, the capital city of Mississippi, has shown rapid growth since 1920, increasing from a city of 23,000 to about 83,000. This has not been a wartime mushroom growth but a steady climb in resident population as Jackson becomes Mississippi's leading city. There are no large "wartime" activities in Jackson, although in the early war days the Jackson city airport —Hawkins Field—was converted to a 3,000-man air base training center and today Foster General Hospital is providing medical care for about half this number. The city, however, is aware that the U.S. Bureau of Census lists Jackson as Class A-1—the group of cities with the most rapid wartime growth plus the best prospects of retention of such growth.

The water meter installations are an index to the growth of the city. From Sept. 30, 1939, to the same date in 1940 there were added 824 meters, in the next year 794, and 454 in the following period. That there have been wartime restrictions on building is indicated by the fact that only 203 new meters were installed in 1943 and 204 in 1944. This is a gain of 3,408 customers since Sept. 30, 1938, in a 100 per cent metered city.

During the past 28 years the city has been most fortunate in having the continuous leadership and management of Mayor Walter B. Scott and Commissioners R. M. Taylor and A. F. Hawkins. They have watched Jackson grow and, anticipating demands, have guided the city successfully through the throes of development from a town to a bustling city. They have directed a continuous program of planning for the future that has permitted Jackson to grow without a burdensome debt structure and will soon see the city free of indebtedness.

In 1938, two 500,000-gal. elevated storage tanks were added to the system and in 1939, two 1-mgd. filter units were constructed to bring the filtration capacity to a rated 10 mgd. A study of plant enlargement was started in 1941 and was extended to include the entire water utility in 1942. It revealed the need for a new intake, increased plant capacity, increased clear well storage, certain distribution supply mains and distribution system extensions. A serious situation was uncovered when it was found that there were no detailed records of the distribution system and that the valve and hydrant maintenance records were almost nil. Water meters had not been tested since installation. Technical supervision of filtration had been recommended by the State Board of Health but until early in 1942, it had not been practiced. The city commission took steps to improve the situation and a program of street intersection platting

was instituted to "get on paper" a lot of data usually in the private possession of the water department personnel. A water meter testing program was also started. Ten meters were removed each day for reconditioning and testing, and replaced the next day, care being taken to return meters to their original locations.

During 1943, a construction program was started at the water filtration plant, with the Federal Works Administration contributing 25 per cent of cost. The program consisted of the following major items of construction:

1. Modernization of chemical mixing and flocculation to replace a baffled mixing basin.
2. New settling basin.
3. Two new 2-mgd. filter units equipped with non-metallic underdrains, hydraulic valves, etc.
4. A new covered clear-water reservoir of 1-mil.gal. capacity.
5. A new chemical storage house, dry feeders, raw and treated water meters, chlorine control equipment, etc.
6. A wash tank purchased second hand, dismantled and re-erected.

It was essential that this improvement be completed without interruption of plant operation, as the total treated water storage was only 1.6 mil. gal. It was also necessary to conserve certain critical war materials but standard reinforced concrete design was used. The only serious restriction was in the expansion joint material used in the flumes carrying the settled water. This project cost $240,000 and was completed in 1944. A few short distribution system extensions and ties were made to provide better service to certain areas where war workers were housed. During the construction period J. H. Fewell, superintendent for nearly 40 years, died and was succeeded by Baxter F. Wade, who has successfully guided the utility to this date.

During August 1943 the author tried out the postwar planning program of the Joint Committee on Water and Sewage Works Development, and the city commission, firm in the belief of Jackson's future, authorized the preparation of detailed construction plans and specifications for parts of the water department modernization program omitted at the present because of the war emergency. Also authorized was a study of sewerage and sewage disposal for the city and a report on Town Creek flood control. These items fitted perfectly into the "Blueprint Now" thesis and Jackson was again planning ahead.

It had long been known that the Pearl River intake was a weak link in the system. The original 30-in. diameter suction pipe extending into the river had broken several times and repairs were only temporary. The pumps are horizontal centrifugals in a deep pit and three of the four units are of 1921 or earlier design. Any failure in discharge or suction piping would endanger the pumps and, as the station is not attended, this hazard was well known. In January 1944, a valve failure flooded the station completely and the city was out of water for 24 hours, indicating the necessity for providing a so-called "fool-proof" installation and the use of vertically-driven volute pumps with motors above flood height. Accordingly, in the new intake design one 10-mgd. unit for emergency use and space for an additional unit are provided. The new intake will have a motor-driven screen and space for a second unit. Intake gates are provided at varying elevations. Again it is necessary to construct this new intake

while keeping the old one in use and careful scheduling of construction is necessary. The plans call for a separate screening and emergency pumping structure near the existing pump pit and the piping is so arranged that the new 24-in. raw water line to the treatment plant can be put in service while connection of the new intake to the old pump station is made. The four pumping units would be revised and piping changes made so that two pumps would discharge into the existing 24-in. raw water line and the other two with the new volute pump would discharge into the new raw water line. This construction is scheduled for postwar action and, it is estimated, will cost $179,000. Due to the flood hazard on Pearl River, construction must be done between June and October. This construction will practically complete the modernization of the old plant. The water production works are now named the J. H. Fewell Filtration Works in honor of the long service of the late superintendent.

Rejected by the WPB as not essential during the war was a new feeder main from the pump station to the high-value district. A new 20-in. feeder main was suggested by the N.B.F.U. but the routing would have entailed very expensive construction and interruption of traffic. A new and shorter route was located and the pipe size increased to 24 in. This line includes 7,700 ft. of 24-in. pipe, 1,656 ft. of 20-in., 1,554 ft. of 16-in., 380 ft. of 14-in., 2,964 ft. of 12-in. and 1,151 ft. of 8-in. and smaller pipe. All pipe is cast-iron, cement-lined, Class 150. The line is tied into the distribution system all along the route. The distribution system grid system will be strengthened in various locations, using some 5,592 ft. of 12-in. pipe, 5,494 ft. of 10-in. and 5,016 ft. of 8- and 6-in. tie-in lines. Some 57 valves and 23 hydrants will be added in the distribution system and fourteen valves and five hydrants in the main feeder. The estimated cost of the pipeline work is $170,000. A study indicated that elevated storage desirable for fire protection in the rapidly growing southern industrial section could be best supplied from a properly located 1-mil.gal. tank, so a satisfactory site was selected and obtained and plans and specifications drawn for this system improvement, which, it is estimated, will cost $119,000. Other minor extensions are included under the routine water extension program. Thus, for the postwar program, the water department is ready to advertise for construction bids on $468,000 worth of improvements that will employ all types of labor and be of lasting benefit to Jackson. Jackson's Water Department is ready for the "needs of tomorrow."

Sewage Works Improvements

In the Department of Public Works, Director J. J. Halbert is likewise alert to postwar problems and, after the presentation of a report on sewerage and flood control, he secured the consent of the commission to have detailed construction plans and specifications prepared for two of the sewerage projects —the Buena Vista relief sewer and the Mill Street relief sewer. Included will be 2,486 ft. of 27-in. sewer, 1,342 ft. of 24-in., 3,798 ft. of 18-in., 5,604 ft. of 15-in. and 1,465 ft. of 12-in. and smaller sewer. Several creek crossings of cast-iron pipe sewers with 4 manholes are included. This new construction will provide relief for the present overload sewers and prevent the discharge of laundry wastes, etc. into Town Creek (a dry run branch

that extends through the city. Detailed plans for a collecting outfall and sewage treatment works were held in abeyance with permission of the State Board of Health.

The report on sewerage indicated that some $718,288 could be expended on sanitary sewers and an outfall intercepter. The cost of the designed sewers is estimated at $118,314 and the balance could readily be designed during the construction of the Buena Vista and Mill Street relief units.

Another public works project, long considered by Jacksonians, is the Town Creek Flood Control project. Town Creek is a very flashy stream draining some 8,858 acres of land including Hawkins Field, the municipal airport. Town Creek crosses the main business part of Jackson in an existing covered passageway but numerous foundation piles, pipelines, etc., have seriously obstructed the channel-way. The Illinois Central Railway likewise has by its city freight terminal restricted the channel. Under Mississippi law, the channel is privately owned and therefore it is not readily controlled by public bodies. The lower reaches of the creek, including the congested downtown portion, are subject to backwater from Pearl River and, to prevent Town Creek overflowing the downtown streets and business blocks, any construction undertaken must be studied in light of the possible coincidence of high water in Pearl River and high runoff in Town Creek. Original plans for full control of Town Creek called for an expenditure of $1,585,000 exclusive of land right-of-way costs. Authorization was given to design the entire improvement but the project was cut back to the lower section after the decision of two of the commissioners to retire from office due to old age. In the preliminary report, work on this lower section was estimated to require an expenditure of $954,500, but in the designing a cost of $562,854 was estimated due to the co-operation of the Illinois Central Railway and to the elimination of certain levees in the lower reaches. No pump station is provided but the paved channel-way, U-shaped, 53 ft. across the top and 35 ft. at the bottom, with a depressed center channel, is provided for normal flows. The channel has been widened, straightened and deepened and obstructions removed or compensated for with enlarged flow section area. The lowest reach of the improved channel-way will carry 6,170 cfs., while the improved channel at the upper end of the improvement is designed for 5,390 cfs. —all carried within the channel limits. This project will necessitate a bond issue for construction but, like the water and sewerage improvements, it is "Blueprinted Now!"

Other Postwar Improvements

Another large public works project already under way is the planning of the development of a new 400-acre park adjoining the water works property in the northeast part of the city. In 1944 the city commission acquired 315 acres of high rolling land and some river overflow bottom land from the state of Mississippi for park purposes. The site is admirably adapted for recreation development and two playground areas are being studied by the National Recreation Association in conjunction with the Atlanta training school program for playground leaders. Tennis courts, playgrounds, a ball diamond, a swimming pool and a community building are planned and a small golf course may be added. A 75-acre lake will be created by damming

a small stream flowing through the property. A group of deep wells will be drilled to maintain water levels throughout the year. The overflow bottom land contains some original timber and will be maintained in its wild state as a bird and wild life sanctuary.

Construction plans are complete for a new city warehouse and garage to be erected on land built throughout the years with the refuse from the city crematory. An additional incinerator is also planned. Preliminary sketches are also ready for two new structures about the City Hall square to house the central administrative departments of fire and police. Trafficway studies have been under way for several months and a tentative layout of trafficway improvements has been determined.

Attraction of Industry

Does postwar planning pay dividends? There is no definite answer but Jackson feels that its program has attracted attention of industrialists. The Adler Manufacturing Co., a division of Sears Roebuck, has acquired 127 acres located about 1¾ mi. north of the present city limits for a furniture manufacturing plant. City water, fire protection and sewerage facilities will be made available. A factory of 750,000-sq.ft. floor area is designed. In downtown Jackson, Sears has acquired 1½ city blocks for a city store, parking facilities, etc., and the Gulf Refining Co. has acquired a site for a state headquarters building for production and refining operations. In the southern industrial area, the Armstrong Cork Co. has acquired 15 acres adjacent to the General Electric lamp works and will erect four building units of concrete and tile construction to manufacture asphaltic-mastic floor tile. Another industry just announced is a large factory for the manufacture of toiletries. Other industries have surveyed Jackson recently but definite commitments have not yet been announced.

Jackson is ready for postwar development—as a city of administrative or distribution facilities or as a southern center for manufacturing. Jackson has "Blueprints—Now!"

Postwar Planning in Ontario

By A. E. K. Bunnell

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Presented on Mar. 21, 1945, at the Canadian Section Meeting, Toronto, Ont.

IT was with the realization that Ontario had developed beyond the pioneer stage and that it was necessary to look to the conservation of natural resources to create a fuller community life that the government of Ontario established the Department of Planning and Development.

We have been in the past too prone to clear the land without considering the adverse effects on soil erosion and fertility and on ground and surface water supplies. The result is that in many of the townships, in the southwest portion of Ontario at least, the lack of ground water is so acute that consideration is being given to the installation of water distribution systems at great expense.

There exists, and has existed for some years, considerable legislation on the statute books of Ontario enabling municipalities to plan for postwar development. The most important statutes are:

1. The Planning Development Act, which provides for the mapping of streets in unsubdivided areas in cities, towns and villages; in the case of cities for 5 mi. beyond developed areas and in the case of towns and villages for 3 mi. beyond.

2. The Municipal Act, various sections of which provide for the expropriation of land for highways and other purposes. Section 406 gives municipalities control of the use of land and the use and location of the buildings to be put on the land.

3. The Public Parks Act, which provides for the expropriation and development of parks and other municipal recreational areas.

As yet very few of the municipalities, including many of the larger ones, have done much to take advantage of these acts. Very few of the municipalities have even a basic map showing the contours or elevations of the land, the streets and the buildings on those streets, and the uses to which the land and buildings are put—a prerequisite to all municipal planning.

In the days before the automobile we were compelled to live within very prescribed limits and those limits have fixed the boundaries of our municipalities. Today we find not only fringe developments but whole communities living beyond the boundaries of the original urban municipality, and these communities demand much from the central city in services of one kind or another. The rural municipalities are not organized to handle urban problems and urban controls should be extended to embrace all such rural areas and provide industrial and recreational facilities close by for the urban-minded population. At the same time the rural communities should set up controls to insure that their lands and their amenities do not suffer from the intrusion of subdivision and other urban land uses, for in the past intrusions of this type have in times of depression been the chief cause of the defaults of the municipalities on the borders of the larger

cities and the imposition of increased taxes on agricultural holdings. We can look, over the next few years, for an entirely new municipal setup insofar as municipal boundaries are concerned.

With respect to the smaller communities, it seems likely that over a period of years some of them are going to disappear. They were created in those horse-and-buggy days when industrial activities were conducted on a much more individual and smaller basis than now and the small factory or mill can no longer compete with the larger factory. The small community today is unable to give its people as wide a range of educational, cultural and recreational facilities as the larger community. Consequently a considerable number of people have been drawn to the larger communities.

Some warning against mere "project planning" should be given for project planning loses a great deal of its value unless co-ordinated with an overall plan of the province or the community. It is therefore necessary to think in terms of basic principles. For example, what are the predominating features that sustain the province and the communities in which we live? Are we cultivating and husbanding our natural resources? Are we making our communities serviceable and attractive for living?

If you believe that your community is going to expand it is of the utmost importance that you consider, determine and establish the areas best suited for industrial development, because without industrial growth there can be no expansion. The author is not an advocate of large, top-heavy communities with all their problems of communications, blighted areas, etc., but there is a certain optimum below which communities are unable to furnish the services and amenities required by urban-minded people.

Unfortunately, a great many people, including many municipal officials, have failed to do any sort of community planning, and theirs will be the communities that will be depopulated. That this is so is demonstrated by the fact that the lending institutions are now refusing to loan mortgage money in such communities. The National Housing Act of 1944 expressly says that mortgage loans made thereunder are at the discretion of the Minister of Finance and certainly they are at the discretion of the lending institutions which remain the primary lenders. Furthermore, the act very definitely provides that extended loans will be granted only to those municipalities which in the opinion of the minister are adequately protected by community planning and appropriate zoning restrictions.

Obviously an adequate plan means a protected plan and under the present municipal setup and available legislation this is very difficult. In most communities the councillors are elected for one-year terms. It is to the men associated with water works commissions or other municipal departments, who are appointed and who, by and large, maintain their positions for long periods of years, that the city councillors turn more and more for help and advice. It is their joint responsibility to provide a backlog of public works for employment whenever the emergency arises. After the war the need will be great and it behooves us now to see that the boys returning from overseas will find a strong and resolute people, fully equipped with sound plans of public improvements all co-ordinated on a dominion, provincial and community level, ready to provide them with honorable employment.

Postwar Utility Expenditures

By Harry E. Jordan

IN an address before the Cleveland Conference of the American Water Works Association, Abel Wolman stated that for the ten-year period following the end of the war cities of the United States would need to expend from $218,000,000 to $220,000,000 a year for water works construction to serve new city dwellers, for construction to replace obsolete structures and equipment and for maintenance of equipment and structures still useful.

At that time he recalled that during the 1920–1930 decade, similar expenditures in the water supply field averaged $130,000,000 per year.

Earlier (May 1942) the JOURNAL carried a statement covering "Material Requirements for U.S. Public Water Supply Construction and Maintenance" which revealed that the normal requirements of the industry for metals and metal products aggregated 405,000 tons annually. For each 1,000 persons served by public water supplies, approximately 300 tons of metal are required for the works, and, for a balanced year to year maintenance program, 5 tons of metal per 1,000 persons served are required.

Approximately 86,000,000 persons in 1945 have their normal place of residence in United States cities which have public water supplies and the normal annual population growth rate in these cities totals 500,000 persons. Louis R. Howson and others refer to a weighted average of $60 as per capita construction cost for water works systems, with an aggregate investment of more than $5,000,000,000, in water utility systems in the United States.

Recently, H. F. Lowe, Chief of the Materials Branch of the Office of War Utilities, submitted through his Chief, Edward Falck, to Chairman J. A. Krug of the War Production Board, an estimate of postwar utility expenditures. The report includes three tables and two charts all of which are reproduced herewith because of their value to persons engaged in forecasting construction in the water utility field.

The words "under existing restrictions" mean under the utilities orders in effect in May 1945. The words "with construction open ended" mean with complete removal of all WPB restrictions which limit construction. Actually, since June 2, 1945, an intermediate set of conditions has been effective—order U-1 "open-ends" all water works construction on a nonpriority basis, except buildings with a materials cost over $25,000. This will tend to increase late 1945 construction above the amount shown for that year in the column headed "Under Existing Restrictions" but will not bring the total quite up to the amount which would result with all construction completely "open-ended."

Contrariwise, the continued tight situation with regard to manpower and transportation will tend to hold down the work which can be done in 1945.

The $200,000,000 post V-J annual rate of construction expenditures as estimated by Mr. Lowe is less than the

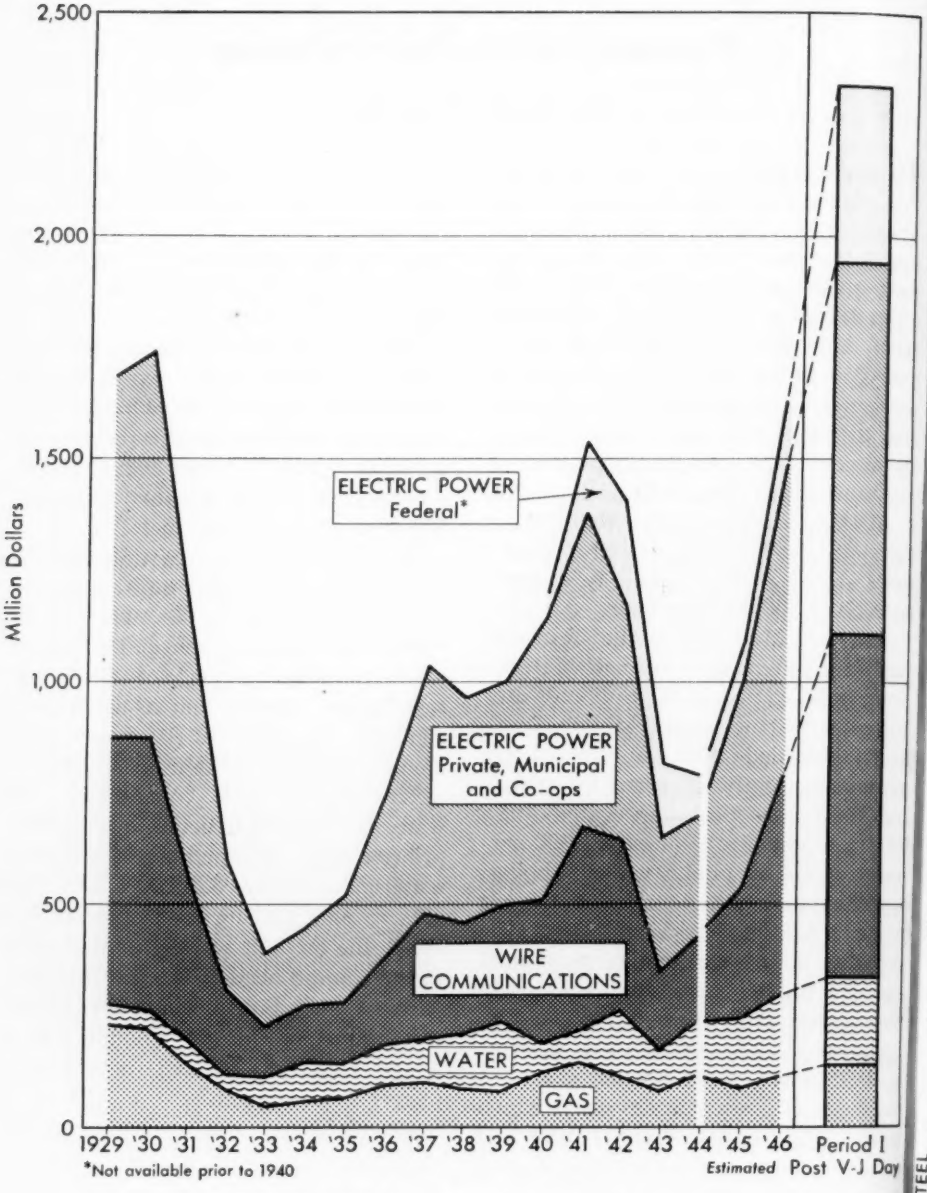

FIG. 1. Public Utility Construction Expenditures 1929–1946 and Post V-J Day

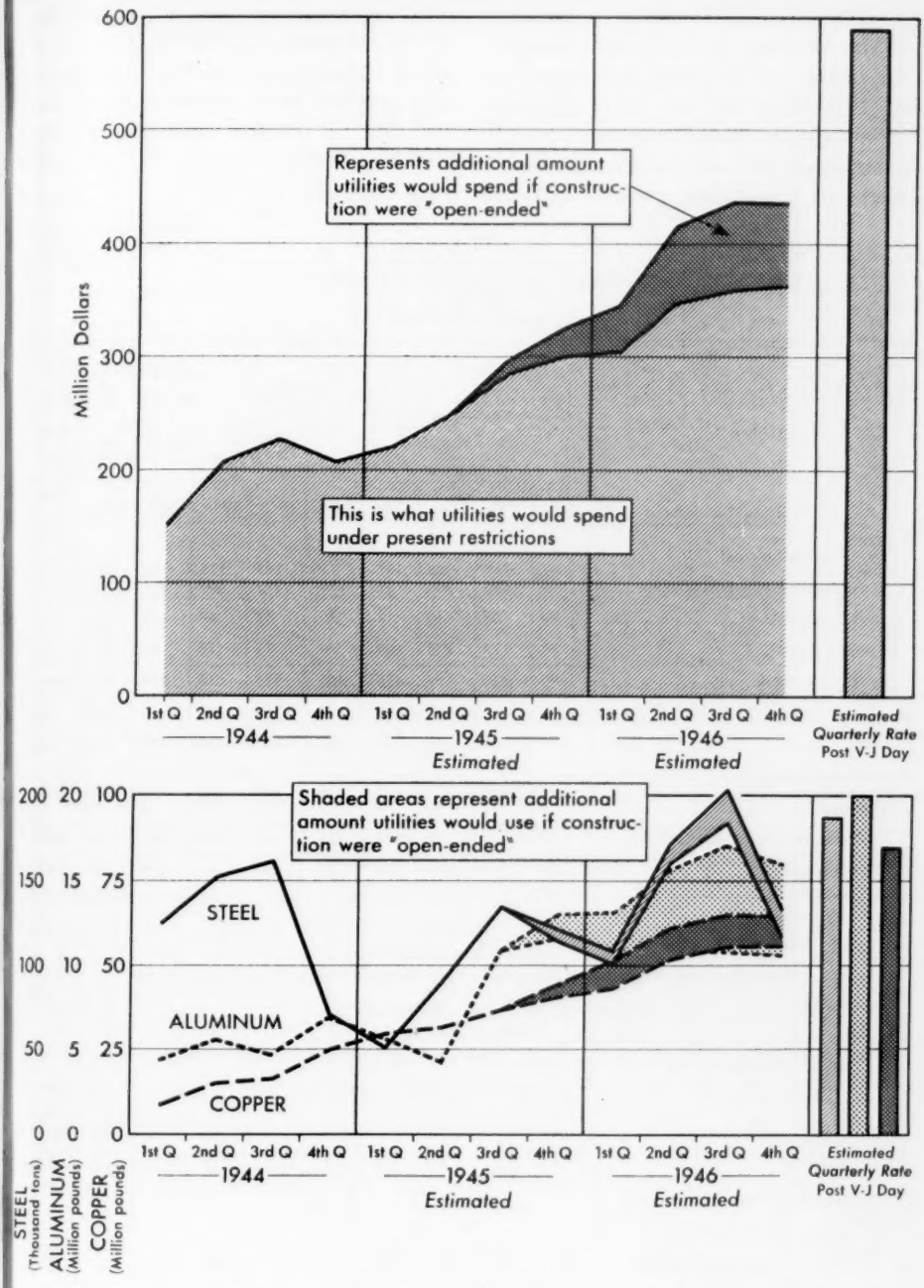

FIG. 2. Public Utility Construction Expenditures in the Post V-E Day Period
Top: Expenditures Including Electric, Gas, Water, Telephone and Telegraph
Bottom: Controlled Material Requirements

$218,000,000–$220,000,000 estimated by Mr. Wolman in 1943, but substantially above the $130,000,000 record of the 1920–1930 decade. Taking into account the increased price level for all construction, as well as the combined effects of population growth and increased annual replacement needs, the WPB estimate of $200,000,000 strikes a fair balance between the pre-depression rate for water works construction and Mr. Wolman's estimate for the post V-J decade.

July 10, 1945.

TABLE 1

Office of War Utilities

Annual Utility Construction Expenditures

1940–1946

(Millions of Dollars)

Utility	Actual Expenditures					Estimated Expenditures				
						Under Existing Restrictions		With Construction Open-Ended		Post V-J Day Annual Rate
	1940	1941	1942	1943	1944	1945	1946	1945	1946	
ELECTRIC										
Private and Municipal										
Generation	207	238	228	157	97	143	175	146	214	250
Transmission and Distribution	354	395	264	137	156	275	305	290	380	450
Rural Co-operatives	79	65	30	12	20	32	60	34	105	145
Federal Plants	50	172	233	169	90	75	75	82	145	400
Total Electric	690	870	755	475	363	525	615	552	844	1,245
GAS	116	140	111	75	110	80	105	80	105	130
WATER	69	75	150	90	120	148	155	155	185	200
WIRE COMMUNICATIONS										
Telephone	310	450	370	165	185	280	480	280	480	750
Telegraph	9	12	12	10	9	12	16	12	16	25
Total Wire Communications	319	462	382	175	194	292	496	292	496	775
Total Utility	1,194	1,547	1,398	815	787	1,045	1,371	1,079	1,630	2,350

TABLE 2

Office of War Utilities

Quarterly Utility Construction Expenditures and Requirements for Controlled Materials

1945–1946

Under Existing Restrictions

(Millions of Dollars)

	1944 Average Quarter	1945				1946				Post V-J Day Average Quarter
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	
Construction Expenditures ($'000,000)										
ELECTRIC										
Private and Municipal										
Generation	24	30	32	39	42	37	43	45	50	63
Transmission and Distribution	39	60	65	75	75	70	80	80	75	112
Rural Co-operatives	5	5	4	10	13	15	15	15	15	36
Federal Plants	23	17	20	20	18	17	20	20	18	100
Total Electric	91	112	121	144	148	139	158	160	158	311

TABLE 2 (Contd.)

	1944 Average Quarter	1945				1946				Post V–J Day Average Quarter
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	
GAS	28	15	15	25	25	20	30	30	25	32
WATER	30	32	37	40	39	35	40	40	40	50
WIRE COMMUNICATIONS										
Telephone	46	55	65	75	85	105	115	125	135	188
Telegraph	2	3	3	3	3	4	4	4	4	6
Total Wire Communications	48	58	68	78	88	109	119	129	139	194
Total Utility	197	217	241	287	300	303	347	359	362	587
Controlled Material Requirements										
Steel ('000 tons)	127	50	88	135	115	99	161	188	115	187
Copper Wire and Cable ('000,000 lb.)	16.1	27.9	30.3	36.5	40.8	43.8	51.1	54.2	55.6	86.0
Aluminum ('000,000 lb.)	5.3	5.5	4.0	10.8	11.6	10.1	10.9	10.9	10.5	20.0

TABLE 3

Office of War Utilities

Quarterly Utility Construction Expenditures and Requirements for Controlled Materials 1945–1946

With Construction Open-Ended

(*Millions of Dollars*)

	1944 Average Quarter	1945				1946				Post V–J Day Average Quarter
		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	
Construction Expenditures ($'000,000)										
ELECTRIC										
Private and Municipal										
Generation	24	30	32	40	44	41	51	58	64	63
Transmission and Distribution	39	60	65	80	85	90	100	100	90	112
Rural Co-operatives	5	5	4	10	15	20	25	30	30	36
Federal Plants	23	17	20	20	25	25	40	40	40	100
Total Electric	91	112	121	150	169	176	216	228	224	311
GAS	28	15	15	25	25	20	30	30	25	32
WATER	30	32	37	42	44	40	50	50	45	50
WIRE COMMUNICATIONS										
Telephone	46	55	65	75	85	105	115	125	135	188
Telegraph	2	3	3	3	3	4	4	4	4	6
Total Wire Communications	48	58	68	78	88	109	119	129	139	194
Total Utility	197	217	241	295	326	345	415	437	433	587
Controlled Material Requirements										
Steel ('000 tons)	127	50	88	137	122	105	174	204	130	187
Copper Wire and Cable ('000,000 lb.)	16.1	27.9	30.3	38.0	44.4	51.1	60.1	64.9	64.6	86.0
Aluminum ('000,000 lb.)	5.3	5.5	4.0	10.8	13.0	13.2	15.5	17.0	16.2	20.0

New York State Mutual Aid Program

By Earl Devendorf

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Presented at the 1945 New York Section Regional Meetings: May 22, Rochester; May 23, Syracuse; May 24, Albany; May 25, White Plains

THE New York State Mutual Aid Water Supply Program was born of wartime necessity and was designed to assist local water supply and sanitation authorities in preparing for emergencies and to facilitate prompt aid from adjoining or neighboring communities. It was developed as a part of the mobilization of the state and its municipalities promptly and effectively to safeguard or restore water service in the event of either wartime emergencies or peacetime catastrophes.

The New York State Legislature passed an act which constituted Chapter 574 of the Laws of 1942 and provided the needed authority for carrying out the objectives of the program. The legislation was the result of a joint study and recommendation of the conference of mayors and the town association and a committee of the legislature.

As Assistant Director of the Division of Sanitation of the New York State Department of Health, the author was appointed State Water Supply Co-ordinator to organize and direct the operation of the Mutual Aid Water Supply Program in New York State. Under this program the state was divided into 22 zones, which are coterminus with the boundaries of the existing state health department districts except for Westchester, Nassau and Suffolk counties which comprise separate zones. A key water works official was appointed as zone co-ordinator in each zone and the district engineers of the New York State Department of Health and the county sanitary engineers of Westchester, Nassau and Suffolk counties were appointed as assistant zone co-ordinators.

A manual for the instruction, information and guidance of local water authorities was prepared and has been printed in book form. A useful reference text, it has enjoyed wide distribution. It is still in demand and copies are yet available.

Soon after the adoption of the program, three-day regional water service training schools were held at five places in the state for the purpose of training and instructing the key municipal water works personnel. Later 35 local schools were held by the zone co-ordinators and local water supply authorities, at which 2,500 volunteer and regular water supply personnel received instructions in accordance with scheduled lessons outlined in the manual.

These schools were conducted with the co-operation of the Bureau of Public Service Training of the New York Education Department, the Municipal Training Institute of the New York State Conference of Mayors, the New York Section of the American Water Works Association, the Na-

tional Board of Fire Underwriters and the New York State Fire Insurance Rating Organization.

During the early months of the war one of the most important features of the program was the mutual aid inventory of water works material. These data were compiled because of the ever-increasing difficulty in obtaining critical materials that might be needed on short notice in case of emergency. The state co-ordinator and the zone co-ordinators, with the co-operation of a specially appointed inventory committee of the New York Section of of the A.W.W.A., made a survey of the water works of the state and established a central pool of information on available water works material. This inventory plan, which was undertaken with the co-operation of the War Production Board and the Office of Civilian Defense, made it possible to obtain water works equipment from existing water works inventories.

Many of the water distribution systems have been interconnected with the systems of adjoining communities. In numerous instances the existence of these interconnections has provided a means of obtaining water from an adjoining supply during emergencies and thus eliminated what might have been a serious breakdown or curtailment of the water supply.

The Mutual Aid Water Supply Program met with instantaneous and widespread favor by municipal and water officials throughout the state and its remarkable progress toward achievement of specific objectives has been due to the wholehearted co-operation of local water authorities and members of the A.W.W.A. and to the loyal and enthusiastic service of the zone and assistant zone co-ordinators in guiding and co-ordinating the work in accordance with well-formulated plans, policies and procedures.

While many of the detailed procedures that were adopted, such as the maintenance of inventories of water works equipment and the training of water works auxiliaries, will now no longer be needed in view of the reorientation of the war effort, many of the fundamentals and original objectives of the program will be of value long after the war is over. The program has resulted in a closer bond between water works superintendents and officials throughout the state than ever existed before. The frequent regional meetings of the water officials incidental to the program have brought a realization that all municipalities have common problems in the maintenance and operation of water supplies.

Many instances have occurred during the past three years where the program has proven of great value in meeting emergencies. The program operates so well that when emergencies arise needed material and equipment or assistance are obtained and services are restored without the knowledge of the state co-ordinator.

Conditions have changed greatly since the Mutual Aid Water Supply Program was formulated. Our country's present position in the war effort and the greatly reduced manpower situation indicate that further expansion of the program is neither practical nor warranted at this time. It is our belief, however, that all water works authorities should make every effort to maintain as many of the benefits gained as may be warranted by present conditions, so that we will have key trained personnel and equipment to meet any emergency that may threaten the safety and adequacy of our public water supplies.

Wartime Maintenance Problems

By Hugh S. Dewey and Harry M. Huy

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Presented at the 1945 New York Section Regional Meetings: May 22, Rochester; May 23, Syracuse; May 24, Albany; May 25, White Plains

THE war, by creating heavy increases in the demand for water, has affected the operations of the Western New York Water Company, just as it has affected operations in privately-owned or publicly-owned water plants in many other areas. These demands for water have taxed the full capacity of the company's facilities even after these facilities were expanded to the greatest extent possible with War Production Board priorities sufficiently high to procure the necessary materials. All means were taken to insure a high output of water and to conserve water for use by industries manufacturing war materials. To accomplish this, all the company's facilities had to be maintained in the best operating condition, leakage from mains held at a minimum and the public requested to conserve water wherever possible and to refrain from lawn and garden sprinkling during daylight hours. It has been the company's first aim "To Keep Water Flowing to the War Industries" so that lack of water would cause no stoppage in the production of war material for our armed forces.

Manpower

The repairmen of this company work long hours in all sorts of weather without complaint. Whether there is snow, sleet, rain or icy winds, when there is an emergency to be met these men carry on their work, using their "Yankee ingenuity" either to avoid a total shut-down or to hold the period of shut-down to a minimum.

The Buffalo region has been a critical labor area and it has been impossible to replace men lost to the armed forces. The company has lost about 12 per cent of its manpower and the remaining men have been called on for longer hours of work to keep abreast of the maintenance requirements, increased by the war demand, of operating the plant and system at or near 100 per cent of its capacity.

At the start of this period the labor shortage was anticipated and certain maintenance work which could reasonably be done by contract was so organized. As an example, service repairs and replacements, repairs of small distribution leaks and other incidental work are scheduled to keep one particular contractor with a very small crew busy 100 per cent of the time. Contractors are faced with the same manpower problems, but with the full use of their equipment have been able to do the work. This is well illustrated in the laying of 700 ft. of 16-in. pipeline, where the crew consisted of the contractor, an assistant and one laborer, who did all the work of ex-

cavating, laying and backfilling. A sizeable emergency force of plumbers, contractors, etc., together with their equipment, has been available for emergencies in the immediate vicinity. These men were trained under the New York State Mutual Aid Program (see page 736, this JOURNAL). Although it has not been necessary, fortunately, to call on them, their availability has been most important, and there have been several instances where timely aid has been given either by nearby plants or auxiliary forces.

Much paper work was involved in keeping the local Selective Service advised on the status of the men and their importance to the operations. There are a few plants where all the key men, engineers and foremen are over draft age, so they were not encumbered with this work and worry. William A. McCaffrey of Oswego advises that this is the situation there.

Transportation Equipment

Under ordinary conditions it has been found economical to replace trucks and automobiles at the end of 50,000 to 60,000 mi. Under war conditions this equipment continues to operate after passing the 100,000-mi. mark. By careful maintenance of the trucks and cars we have been successful in preventing the loss of use of this equipment for any serious length of time. The repair expense of this equipment has necessarily been high but at no time has work been delayed due to lack of transportation equipment. To add to the transportation problem, numerous instances have occurred where it was necessary to haul materials purchased from a nearby vendor, who was unable to furnish the usual transportation in the time required.

Water Supply and Pumping

War plant requirements increased velocities in sections of the intake pipeline from Lake Erie, from 4.5 to 7.0 fps. This increase moved foreign material, which had accumulated in the pipe over the years, into the low-lift pumps, increasing the problem of maintenance of these pumps. Failures of ball bearings and shaft sleeves occurred more frequently. The company has always considered it advisable to have replacement bearings on hand and maintenance work has not been delayed for lack of these. The company also recognized the necessity of having close relations with a local machine shop, equipped to make sleeves, shafts and other appurtenant parts. Such arrangements were made and it has been possible to call on the aid of a local machine shop 24 hours a day. When the regular manufacturers of equipment could promise delivery only after five weeks or more, it has been possible to get the necessary parts, in most cases, in a few days and never more than one week. Similarly, all the pumping equipment has been repaired in this manner. Critical parts that could not be made by local machine shops have been carried in stock.

Knowing that demands for water would require operating the filters at or near a rate of 3 gal. per sq.ft., the company, before the manpower situation became too critical, overhauled all the filters. The work was done in freezing weather and all material had to be handled inside. This required the overhauling to be done by removing the filter material from one filter, screening and washing it and then storing it in portable bins erected in an adjacent filter box. The sixteen filters were repaired in the same man-

ner, with never more than two filters out of service at one time.

Also, to insure uninterrupted service during repairs of pumping equipment and major transmission pipelines, emergency connections were made between the Western New York Water Company system and that of the city of Buffalo, to be used mutually by either. Only in one instance were the pipelines of the two systems physically connected. The other connections were so designed that a standpipe or hydrant was erected on one system adjacent to a similar installation on the other, the connection to be made by hose when required. Since the hydraulic level is higher in the company system than in the city, these hose connections allowed for the installation of portable pumping equipment.

Transmission and Distribution

Heavy demands added also to the problems of maintenance in the transmission and distribution lines. Before 1941 about 18 mi. of transmission mains, mostly 24 and 16 in. in diameter, were cleaned not more frequently than once a year. Since the start of the war, to insure the high carrying capacity of these lines, cleanings were scheduled twice a year and provisions made for more frequent cleanings, if required.

Urgent repairs of blown joints in transmission mains were usually accomplished without total shut-down. These repairs at times required considerable ingenuity to accomplish under pressure. With a 6-in. portable gasoline-driven pump, the water could be held down to working levels and a series of lead wedges were driven home to stop the leak sufficiently to allow installation of a clamp for joint permanency. Where the pressure of the escaping water prevented the holding of lead wedges, soft wood wedges were used with success. Where cracked pipe occurred, shut-downs were held to the least possible length of time by use of large portable pumping equipment to draw off the leaking water, so that all necessary work, up to the actual replacing of the pipe itself, could be done before the shut-down.

John H. Burwell, Engineer of the Schenectady Department of Water, reports a novel method of repairing a 6-in. main, which had sheared off. Not having a 6-in. split repair sleeve on hand, they utilized the backs of two 6-in. × 4-in. tapping sleeves, avoiding the necessity of cutting the 6-in. pipe and using a solid sleeve.

In several instances contractors who were excavating adjacent to important transmission lines, hooked services and pulled out the corporation cocks. The resulting spurting leaks were stopped by driving a round wooden pin, gradually tapered to a point, into the hole. Old broom handles were very useful in this repair, as they gave a length of 3 to 4 ft. for driving. After the pin was driven, it was sawed off flush with the pipe, the tapping machine centered over the now-closed hole and the pin drilled out, the pipe retapped and a new corporation cock installed.

It became necessary to clean one of the distribution reservoirs having a capacity of 10 mil.gal. Cleaning was accomplished in a shorter time than was first anticipated by using an OCD auxiliary pumping unit borrowed from a local fire department. With this unit the very low pressure in the pipeline leading to the reservoir could be boosted and water streams of high velocity could be used for hydraulic removal of the deposits in the reservoir

Materials

Due to the foresight of water works operators, most of the large plants had a sufficient stock of pipe, fittings, repair parts for valves and hydrants, etc., on hand for maintenance work. This is well illustrated by letters of comment that have been received from Clayton O. Johnson of Jamestown, W. F. Davies of Gloversville, Harry B. Miles of Utica, James F. Conlan of Scarsdale, James Harding of Westchester County, and others, all of whom state that their 1941 stock has been ample to meet their requirements. This, together with the New York State Mutual Aid Program, did much to make materials for repairs readily available to all water plants, small and large, to public services other than the water utilities and to industries. The experience of the Western New York Water Company was that more material was sold to other utilities and to war industries, than to water plants.

The WPB, in granting high priorities and aiding in locating material for maintenance and construction, assisted greatly in the procurement of necessary materials.

In general, materials which were difficult to obtain and required a long period for delivery were pumps, motors, electric equipment and engine parts. R. Gordon Yaxley of Waterford and William A. McCaffrey of Oswego relate similar experiences with slow deliveries for this type of material. Delivery of meter repair parts has been slow and recently the delivery of joint clamps and repair sleeves of the rubber-gasket type has been lagging, due, of course, to vital requirements of the armed forces.

Conclusion

During this war, many of us have had to devise means for doing repair work in different and novel ways, some of which can be used to advantage when peace comes. Now is the time to analyze the work as it is being done during the war years, in order that we may profit by retaining the useful methods which contribute to the better maintenance of water works systems.

When war restrictions and the myriads of paper forms now necessary to inform governmental agencies of our operations and our need for materials, manpower and equipment are gone, the water works operator can again direct all of his efforts toward the better operation of his plant. It is to the everlasting credit of the operators of all plants, large and small, that with the splendid co-operation of state and federal agencies, the National Board of Fire Underwriters, the Mutual Aid Program, etc., the record of continuous operation in New York State has been excellent.

System Maintenance

By Ernest L. H. Meyer

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Presented on May 24, 1945, at the New York Section Regional Meeting, Albany, N.Y.

WHAT are the duties of the water works man pertaining to the maintenance of a water works system? Prerequisite is the ability of the man in charge to organize and systematize his water works department. Only in so far as the "top" man has trained himself and those under him, and established good relationships between himself, his staff and the customers, will his administration of the affairs of his department be successful. All kinds of complaints, justifiable and unjustifiable, are received, and they must be handled with a great deal of tact. The customer must be fully appeased and complaints should terminate with a comprehensive understanding and in a friendly atmosphere.

The executive must know his water works system thoroughly. He must know where the weak spots are and must be planning continuously to strengthen them. This is not always an easy task, often undertaken with limited funds or under a supervisory body inclined to "let things ride."

The water works man should always put himself "on record" with his recommendations and his reasons for them. Too often, after an emergency, the "buck is passed" to the poor "super." He has no comeback if he has not placed himself on record.

He is responsible for seeing that the necessary equipment, tools and materials are instantly available for making repairs as quickly as possible and with the least inconvenience to the consumer. He must therefore have sales tact, that he may convince his board of the importance of having these essentials on hand at all times. A water works maintenance department cannot be too well equipped and supplied to perform the duties required of it, many of which are of an emergency nature. A screwdriver, hammer, wrench, boat pump, a handful of nails and screws and a few strands of bailing wire will not do the trick.

The head man of the water works should be one who has had some technical and quite a lot of practical training in the water works field. It is also important that he be free of political obligations. He should be given wide latitude in selecting and retaining the personnel under his supervision. This personnel for the most part should have experience, be well trained, efficient and faithful to the job. The job is not an easy one, particularly where one is subject to call at any time, day or night, Sundays or holidays, regardless of weather conditions. The compensation of each water works employee should be adequate for the particular job held.

Maintenance Activities

When the system has been constructed and placed in operation, maintenance begins. First to be cared for

are the watersheds and reservoirs. The watersheds comprise all of the lands which contribute drainage, or runoff, for the water supply of the system and as such must be rigidly supervised. The uses to which these lands can be put are restricted by rules and regulations enacted by the state health department, enforced by the utility and designed to protect the sanitary quality of the water at all times. They usually safeguard against trespass, hunting, fishing, bathing, boating, etc. Where habitation existed on the watersheds prior to their development as such, and is permitted to be continued after the development for reasons of economy, the burden of requiring sanitary conditions to be initiated and maintained at all times is a function of the water works utility and its personnel. Therefore a constant inspection of the watersheds must be effected to see that the rules and regulations are complied with and that all violations are promptly abated or prosecuted when necessary. The watersheds must be thoroughly posted with signs calling attention to the fact that they are such, and to the regulations protecting the land, any violations of which are subject to prosecution. These signs should be protected from the action of the elements and of rodents in order that they may be readable at all times. They must be periodically inspected and renewed when necessary.

Then comes the care of the utility-owned lands on the watershed, some timbered and others abandoned farm lands. The latter should be reforested to provide cover for the conservation of the ground waters and the retardation of spring runoff. The natural forests and the reforested areas should be administered by a capable and experienced forester. The employment of a trained person will pay worthwhile dividends when the timber reaches maturity and becomes marketable.

The fire hazard in timbered lands is always great and every precaution should be taken to guard against it. To this end well-planned, laid-out and constructed roads and trails on the watersheds, to make every portion thereof easily accessible with fire fighting equipment and men, are of great importance.

The work on the watersheds and reservoirs consists mainly of:

(1) The repair of the roads and trails to keep them in good condition for the type of transport for which they may be designed, involving surface grading, cleaning of drainage ditches and culverts, repairing bridges, mowing brush beside the roads and in the trails, snow-plowing in the winter, etc.

(2) The repair of the utility-owned buildings on the watersheds—roofing, painting, mowing brush around them, repairing broken windows, replacing decaying timbers and siding, repairing or replacing damaged and broken hardware, etc.

(3) The care of the reservoir structures—dams, spillways, intake structures, screens, sluice gates and valves—involving the repair of eroded embankments, rip-rap displaced by the action of ice, disposal of debris which has fallen into the reservoirs and has floated to the shore lines, mowing brush and weeds around the edges of the reservoirs, mowing grass and trimming shrubbery where sown or planted, cutting ice around the intake structures during the winter months, control analysis of the impounded waters and mass treatment thereof when necessary

to control algae and microscopic organisms, control of flow of the stored waters to the distribution reservoirs, constant vigil and labor to keep the water courses flowing into and between the reservoirs clean and unobstructed, control of the waters being delivered from the distribution reservoirs into the supply mains, chlorination of water to control coliform organisms, trimming and thinning the planted forests so that the greatest benefits may be derived therefrom.

These are some of the principal activities which can be classified as "maintenance" between the source of the supply and the supply mains when the supply is surface water. In ground water supplies, there are wells of a number of types, dug and curbed or driven and cased, with constant vigilance necessary to keep surface drainage away. Involved in maintenance are: repairs to the pumping equipment and the automatic devices connected with them; repairs to the buildings housing the equipment; care of the grounds around these structures, which quite frequently are landscaped; constant attendance to the mechanical operation with its recorders and charts and the various units making up the pumping equipment, and their sequence of operation under varying conditions of demand on supply.

Pipelines

Little trouble should be anticipated from the supply and distribution pipelines. Any serious break is recorded by the pressure gage and the master meter of Venturi or current type. The pressure gage should be housed at a convenient central point where someone is always in attendance during the business hours of the day—say in the storehouse or the main office. A second gage with an electrically-activated alarm bell should be installed where there is a 24-hour service of personnel—as, for instance, the police or fire department headquarters. Any serious break in the mains will immediately be sounded by the alarm bell (released by the drop in pressure) and word can promptly be transmitted to the water works crew. The master meter should, of course, be installed on the principal supply mains so that all of the water diverted to the distribution system will be measured and accounted for. Where an automatic chlorinator is used, it should be installed at the master meter for control of the chlorine flow.

All these mechanisms are equipped with recording devices which are usually of the 24-hour type, and which require a visit each day at a stipulated hour for the changing of the recording charts, the winding of the clock mechanisms, the filling of the recording pens or the adjustment of the measuring devices.

The supply mains, which are usually laid across the country, must be frequently inspected for minor leaks which have little, if any, effect upon the pressure gage or meter recordings. In the populated districts, where the distribution or grid system is installed, vigilance is not quite as important a factor, as anybody noticing water flowing on the surface will promptly notify the water works office. Mains must be inspected whenever a cut of any size is required, to determine whether the pipe is tuberculating on the inner surface. If it appears that such is the case, test flows must be made to determine the constancy of C in the Hazen-Williams formulas for flow. If an appreciable decrease is evident it will probably be necessary to have the

mains cleaned periodically. It is advisable to have leak surveys made periodically so that any hidden leaks that may have developed may be isolated, dug up and repaired. Gate valves on the system should be operated by opening and closing at uniformly spaced intervals of time so that any gate found broken, leaking or not closing properly can at once be repaired. The roadway valve boxes or manhole covers housing the valve quite frequently become covered up during street repairs. A close watch must be kept so that level adjustments for the box or manhole cover can be promptly made by raising or lowering it to the level of the street surface.

Fire hydrants are always a thorn in the side of the water works man when their inspection is his responsibility. Hydrant inspection, of course, should be frequent. If it is not, damaged hydrants may not be discovered until they are needed at a fire. A break may accidentally result from a heavy vehicle backing into or sideswiping the hydrant with just sufficient impact to crack the barrel but not to dislodge the stem and valve. When an attempt is made to use the hydrant, the water gushes through the fracture in the barrel, which is usually just below the ground level. There are many systems which have no gate valves installed on the hydrant laterals so that when it becomes necessary to repair a hydrant, a stretch of main on the street has to be shut off, causing great inconvenience to consumers. Whenever such an emergency arises the opportunity to install a gate valve in the lateral should be seized.

Services

The details relative to house service connections are generally familiar. Most common is the registration of complaints concerning humming sounds throughout the premises. Investigation by the utility personnel usually discloses a leak on the line. Is it the obligation of the utility or the property owner to repair this? That question has to be determined. There are calls for service to be turned on or off. Often a time has to be arranged when the property owner may have someone present during the operation so that there will be no question of whether the job has been accomplished. A failure to complete the operation may mean a damage suit against the utility. While the classification is not always agreed on, the making of new and renewal taps is usually a function of the maintenance crew. Where a renewal is requested, the property owner often wants it made at a point other than where the original connection was made, which necessitates another street excavation and an additional cost for shutting off and disconnecting the old service at the main. In previous years this requirement was not strictly enforced, with the result that leaks occasionally occur at the old connections, usually in the old pipe. It is the maintenance crew's duty to locate and shut off the old connection.

Periodical inspections of service fixtures should be made in some instances, usually where the water rents are assessed on the "flat rate" basis. The purpose of the inspection is to uncover violations of installations on which rents are not being paid and to require the property owner to keep his fixtures well packed as a guard against leakage and consequent waste. Where water is sold through meters these conditions are not serious. However, the water works man then has to cope with complaints of faulty meter registration.

Any water works utility having 25 per cent or over of its services metered should own a Meter-Master. The records of this instrument of the use of water over any given period of time usually stop all arguments as to the correctness of the meter registration. The meter will quickly correct wasteful uses by the consumer, who discovers that he pays for that amount of water which passes through and is recorded by the meter. The meter department has to be well equipped for testing and repairing meters. This may be quite a busy department where the water supply is from surface sources and is untreated by filtration.

Miscellaneous

Searches for and inspections of cross-connections have to be frequently made to detect any violations and to see that the required check valves on such cross-overs are free and functioning properly.

Surveys for lost mains and service pipes can become quite difficult, especially in the vicinity of other underground utilities where the electrical impulses of the "finder" often stray far afield from the water mains and record instead some other and foreign piping.

The keeping of all motor equipment, tools and machinery in first-class operating condition, ready to go at a moment's notice, is an important function of the maintenance crew. A skilled mechanic should be in charge of this work and should be held strictly accountable for its condition.

The activities of the water treatment plant, the author feels, are part of "operation" except when renewals, replacements and repairs have to be made, and this work should be done by the maintenance crew.

The maps and records of the entire system comprise one of the most valuable of all its assets, and are especially important to the maintenance division. Without complete records its tasks would be most difficult and trying. Maps and records should be complete in detail and all corrections should be kept strictly up to date. This work would include the records of the location of all gates and service shut-offs by reference measurements and sketches; all chart records of pressures, flows and treatment, as well as any other records which would be of inestimable value in the future when planning for betterments and expansion of the system. Where these records are daily or weekly they can be consolidated into monthly or yearly graphs to conserve filing or storage space. All records should be kept in fireproof vaults for protection.

The author hopes that he has not digressed too far from the subject of "system maintenance." It is a very fine line which divides the operational functions from those of strict maintenance in the small water plant. This line is probably more clearly defined in the larger utilities which have separate departments set up with their duties ascribed.

Management of Municipally-Owned Water and Electric Utilities

THERE was recently received in the office of the American Water Works Association an inquiry related to the form of organization and management of the electric and water utilities in cities where both services were owned and operated by the municipality.

The inquiry related to conditions in cities having 50,000 or greater population. A survey of the situation was made and here follow brief statements outlining the plan of management and operation in the 23 U.S. cities of over 50,000 where water and electric utilities are owned by the municipality.

In Cleveland and Columbus, Ohio, Detroit and Kalamazoo, Mich., Lincoln, Neb., and Fort Wayne, Ind., the municipally-owned electric utilities furnish only part of the electric services to the municipalities. Private electric companies also render service within the limits of these municipalities.

The survey discloses that there is no uniform system. The manner of appointment of the management group or board for the utilities varies widely. There is no consistency in the degree of integration of the two services.

The integration of the two services in the city of Kalamazoo is striking and will be reviewed in the JOURNAL at a later date. A survey of the conditions in other population groups and a record of the results of such surveys in the JOURNAL are also planned.

Austin, Tex., has the council-manager form of government. Five councilmen are elected biennially by popular vote. The five candidates receiving the highest number of votes are elected. The five select one of themselves to serve as mayor. They also select the city manager, city treasurer, city clerk and various advisory boards.

The city manager is the chief executive and all the main departments, such as utilities, finance, public works, health, safety, legal, etc., are administered and departmental heads selected by him. The water, electric and sewerage departments form the utilities division, and function under the direct control of a director of utilities. Each department is headed by a superintendent. The accounting office handles water, light and sewerage accounts. At the present time there is no charge for sewerage service, except outside the city limits. Consequently, the number of sewer accounts is very limited. Meter readers read both water and electric meters monthly, and the bills to the customers are for both water and electric services. The operating funds for the sewer departments come from water and light revenues.

Cleveland, Ohio, has a department of public utilities which is a department in the city government provided for by the city charter. The director of public utilities is appointed by the mayor and is a member of the mayor's cabinet, called the "board of control." The director of public utilities has the control and supervision of the department of public utilities. The department of public utilities is separated

into divisions of water and heat, light and power, and sewage disposal, each operating under the direction of a commissioner.

Columbus, Ohio, is organized under its present charter with three departments, namely, service, safety and health. The water works, the electric utility and the sewage treatment system are operated as separate and distinct divisions under the department of public service.

Detroit, Mich., has water and electric utilities which are operated separately under the direction of boards consisting of four members. The board in each case acts as a policy-forming body and the law stipulates that the active direction and management of the property be under the general superintendent of each department.

The department of water supply operates the sewage treatment system of the city. Sewage treatment is financed by a surcharge on the water bills of those customers served by the sewage treatment system. The water department collects the revenue, administers the plant and pays the expenses, which include the interest and the principal of the sewage treatment bonds. The immediate head of the sewage treatment plant is known as the engineer of sewage treatment, and he reports to the management of the water department in the same manner as heads of the various sections of the water department.

Fort Wayne, Ind., operates three utilities—water, light and sewage—all under the supervision of a superintendent of utilities. He reports to the board of public works, and the board of public works to the mayor. The three utilities are separately operated with an independent department head in charge of each one. The three department heads, of course, report to the superintendent of utilities. The sewage utility is separate and distinct from the water utility; however, the sewage charges are billed on the water invoices.

In addition, the city has three departments, water construction, light construction and sewers, all under separate heads, who also report to the superintendent of utilities.

Glendale, Calif., has the council-manager form of government. All departments report to the city manager and the city council. The city operates both the water and the electric utilities under the public service department. All operating and construction work of the department is under the supervision of a superintendent. The city entered the business of operating its own electric utility by purchasing a private company in 1909. In 1914 it acquired three private water companies. The city has no sewage treatment plant, disposing of its sewage through an outfall with the city of Los Angeles.

Hamilton, Ohio, operates its own water, gas and electric facilities, but has no sewage treatment plant. These utilities are operated as a department of utilities under one director. Each branch has a superintendent. All accounting is done in the department of finance under a special utilities accountant, who makes a daily report to the director of utilities.

Holyoke, Mass., owns the water, gas and electric utilities in the city. The water works is operated by three commissioners, who are elected by the

board of aldermen and who have sole supervision of the water department. The department collects all water rents, has its own treasury and pays all its own bills.

The gas and electric department also has a commission of three members, who are appointed by the mayor. This commission directs and controls the manager, who has full charge of the operation of the plants. The department collects all its own bills, but the receipts are turned over to the city treasurer and are used to pay the expenses of the plants.

The sewers of the city are built and maintained by the board of public works, which also consists of three members appointed by the mayor. This board has charge of the construction and maintenance of streets, sidewalks, sewers and public buildings, the cost of which is paid from general taxation and betterment assessments.

Each of the three public departments is governed by statute and they are independent of one another.

Jacksonville, Fla., has a system which is operated under the following committees: the legislative committee, which consists of the mayor and the city council, serving in elective offices, for which no salary is paid; the administrative committee, which is also elective, but which does receive a salary and which consists of five commissioners—the commissioner of public utilities; the commissioner of parks, zoo and finance; the commissioner of highways, radio and airport; the commissioner of public safety; and the commissioner of health sanitation.

The department of electricity and water is headed by a general superintendent. There are five water pumping stations and a number of electric substations. Operations are covered by a single administration and are handled by common crews.

The commissioner of highway, radio and airport has supervision over the city engineer, radio and airport, and the city engineer has supervision over streets, etc., and sewers. The department of public utilities has a separate engineering department.

Kalamazoo, Mich., operates both an electric and a water utility, with a single manager of both appointed by and holding office at the pleasure of the city manager. Consolidation and integration has been applied to every activity possible. The general office, the commercial office, billing, meter reading, etc., are all handled by the same personnel. The electric utility has a line crew, which usually takes care of the distribution system of the electric utility. However, the water utility owns some overhead wires (being control wires for the control of pumping facilities) and the electric utility line crew looks after them. The water utility, on the other hand, has men quite familiar with underground construction, and these same men install water mains and underground electric conduits. The accounting is kept separate and distinct. A separate set of books is kept for each utility, and every man in both organizations, from the manager down, turns in a daily time slip showing the distribution of his time to the different accounts of the two utilities.

Kansas City, Kan., has its water and light utilities, as well as a municipal airport, all controlled by a board of public utilities. The board members are local businessmen who are elected

for four-year terms at an annual salary of $100. The board meets weekly. It employs a manager of production and distribution and a manager of collections and accounts. The operations of the water and electric plants are integrated to the fullest possible extent.

Knoxville, Tenn., has placed the purchase, production and distribution of electricity and water, both within and without the limits of the city, and the agencies and facilities used for such purposes, under the jurisdiction, control and management of a board, known as the Knoxville Electric Power and Water Board. The board consists of five commissioners, appointed by the mayor and confirmed by the city council. Whenever a vacancy occurs or whenever a commissioner's term expires a new commissioner is selected in the following manner: The city manager (or if no city manager, the mayor) meets with all members of the board, exclusive of any commissioner whose successor is to be nominated at such meeting. Nominations are made at this meeting, but, before any person is nominated, he must receive the favorable vote of both the city manager (or if no city manager, the mayor) and a majority of the commissioners who are eligible to attend and participate in the nomination. Before the nominee becomes a commissioner, he must be confirmed by the city council.

The electric power and water board includes a bureau of water, a bureau of power and a bureau of accounts. The bureau of water controls the operation and management of the public water supply system. Billing and collection for water service is handled by the bureau of accounts. A similar situation exists in the municipally-controlled electric utility.

The Knoxville sewerage system is under the supervision of the general city government and under the direct charge of the city engineer. There is no sewage treatment plant.

Lansing, Mich., operates a combined water, electric and central steam heating department. The utilities are controlled by a board of eight men who are appointed by the mayor and who serve for four-year terms. Two are appointed each year. The board has full and complete control of the utilities. It fixes rates, establishes policies and controls expenditures of all money; appoints a general manager, to whom all personnel is responsible and who has general charge of operations; and appoints a secretary who is responsible for the moneys of the board. Water, electric and steam heating service are integrated into one system. The water department does not operate the sewage treatment system, which is operated by the city engineer.

Lincoln, Neb., operates a combined water and electric department which furnishes nearly all the water used in Lincoln, electric energy for all water pumping and street lighting in the city, and approximately 20 per cent of the residential and commercial electric business in the city. The water and electric utilities are by ordinance designated as part of the department of parks, public property and improvements, which correspond to what is generally know as a public works department in many other cities. At the present time, this department includes water and electric utilities, parks, streets, sewers, paving repair, plumbing and building inspection, municipal airport and recreation. The director of this department is appointed by the city council, and his compensation is

determined by the same body. The director of this department is also city engineer, for which duties he receives additional compensation.

Sewage treatment in Lincoln is handled by Sanitary District No. 1 of Lancaster County, which is a separate governmental agency, created by a special legislative act. The water department, therefore, has nothing to do with sewage treatment.

Los Angeles, Calif., has the country's largest municipally-owned water and power system and its general policies are established by a board of water and power commissioners. Board members are appointed by the mayor, subject to approval by the city council. Administration of the property is headed by a general manager-chief engineer. In charge of the water system is a chief engineer of water works-deputy general manager, while in charge of the power system is a chief electrical engineer-deputy general manager. The auditor and controller is in direct charge of auditing, accounting, purchasing and commercial divisions of both the water and electric systems.

Memphis, Tenn., owns and operates the Memphis Light, Gas and Water Division. The division is governed by a board of light, gas and water commissioners, consisting of a president, a vice-president and a commissioner. The first two are full-time men, appointed by the city commission for terms of two years. The operation is a joint one in some respects. For example, all meters are read by one meter department, and one billing department makes bills. Electricity, gas and water are billed on a single bill. Other joint activities are complaint, credit, meter records, cashiers, commercial and bookkeeping. The actual operations and maintenance of the three utilities are separate. Each utility has a director.

All sewers and matters pertaining to sewage are under the control and supervision of the city engineering department.

Nashville, Tenn.—The water works department is a department of the city government, the chief administrative official being the elected water commissioner. The active direction of the department is under the superintendent and chief engineer-director, who is responsible to the elected water commissioner. The electric utility operates under a separate power board, the members of which are appointed by the board of administration, and confirmed by the council.

The city does not have a sewage treatment plant; however, the sewerage system is operated under the supervision of the director of public works, who is responsible to the elected commissioner of fire and public works.

Orlando, Fla., has a utilities commission consisting of five members, with the mayor as an ex-officio member. The utilities commission by a majority vote nominates and the city council elects all new members of the utilities commission and all vacancies are filled in like manner. The utilities commission has full authority over the management and control of the electric light and water works plants in the city of Orlando, and elects and discharges at its pleasure each employee of the city whose time and services are wholly employed in the discharge of duties directly related to the electric light and water works plants. The utility system of Orlando is operated under one general manager, with separate superintendents and crews for the

electric and water departments. The clerical and office work is handled by the same employees, but all revenues, expenses and construction are kept separate by allocation to the two departments. The final net revenues of the two departments combine into one accumulated surplus for accounting purposes. All funds except such as may be turned over to the city for retirement of bonds and donations to general city funds are handled by the Orlando Utilities Commission and kept by them as if privately owned.

Pasadena, Calif., operates both water and electric utilities. Each utility is a separate department, reporting to the city manager who is responsible to the board of city directors. There is no public works department or utilities board. The sewage treatment plant is also set up as a separate department, reporting to the city manager. The departments co-operate with each other and pay for any service done by the other departments.

San Antonio, Tex., operates both water and electric utilities; however, the two boards are separate and distinct. In the conveyance of the water company from the private concern to the city, about twenty years ago, a board of five was appointed. One member is the mayor, ex-officio, and the board is self-perpetuating. The electric utility is known as the "city public service board" which provides both gas and electric service. There is no connection whatever between the public service board and the city water board, except that the mayor is an ex-officio member of both.

Seattle, Wash., operates a water utility, an electric utility and a sewage treatment plant. While not operated jointly, each is under the board of public works, which is made up of the superintendent of water, the superintendent of light and the city engineer, who is in charge of sewage treatment. The superintendent of water is chairman of the board.

Springfield, Ill., operates water and light properties under the jurisdiction of the commissioner of public property, and active management is carried on by the "administrative assistant," under whom the superintendent of water distribution and the superintendent of light and power function. Staff assistants to the administrative assistant are the superintendents of lake land and of new business, the auditor and the chief chemist of the water purification plant.

Tacoma, Wash., has a commission form of government consisting of a mayor, who is commissioner of public welfare; a commissioner of public utilities, under whose general direction the light department, water department and belt line railroad are operated; a commissioner of public works; a commissioner of finance; and a commissioner of public safety. The utilities of light, water and belt line railroad are each administered by a superintendent, independent of other departments. The sole source of income of the utility departments is from the sale of services.

The sewer department is not operated as a revenue-producing utility and is not integrated with the Water System, but supervised by the city engineer who, in turn, reports to the commissioner of public works.

The above information was received from the following persons:

Austin, Tex. Albert R. Davis, Supt., Water Dept.
Cleveland, Ohio. G. W. Hamlin, Comr. of Water & Heat.
Columbus, Ohio. C. B. Hoover, Supt., Div. of Water.
Detroit, Mich. L. G. Lenhardt, Gen. Mgr., Dept of Water Supply.
Fort Wayne, Ind. Ralph Hoot, Supt. of Sewage Treatment Works.
Glendale, Calif. P. Diederich, Supt. of Public Service.
Hamilton, Ohio. S. F. Kautz, Water Works Dept.
Holyoke, Mass. James L. Tighe, Cons. Engr.
Jacksonville, Fla. F. A. Eidsness, San. Engr., State Board of Health.
Kalamazoo, Mich. Earl E. Norman, Mgr., City Light & Water Utilities.
Kansas City, Kan. R. J. Duvall, Mgr., Water Dept., Board of Public Utilities.
Knoxville, Tenn. M. B. Whitaker, Supt., Bureau of Water.
Lansing, Mich. Otto E. Eckert, Gen. Mgr., Board of Water & Electric Light Comrs.
Lincoln, Neb. D. L. Erickson, Director of Parks, Public Property & Improvements.
Los Angeles, Calif. S. B. Morris, Gen. Mgr. & Chief Engr., Dept. of Water & Power.
Memphis, Tenn. C. M. McCord, Director, Water Div.
Nashville, Tenn. Robert L. Lawrence, Director, Water Works Dept.
Orlando, Fla. M. W. Brown, Gen. Mgr., Orlando Utilities Com.
Pasadena, Calif. Morris S. Jones, Chief Engr. & Gen. Mgr., Water Dept.
San Antonio, Tex. Warren H. Booker, San. Engr., City Health Dept.
Seattle, Wash. W. C. Morse, Supt. of Water.
Springfield, Ill. S. T. Anderson, Administrative Asst.
Tacoma, Wash. W. A. Kunigk, Supt., Water Div.

The above information was assembled by the staff at A.W.W.A. headquarters, under the direction of the Secretary.

New York City's Water Supply to Outside Communities

By Tobias Hochlerner

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Presented on May 25, 1945, at the New York Section Regional Meeting, White Plains, N.Y.

THE three main sources of water supply for New York City are (1) the watersheds of Schoharie and Esopus creeks in the Catskills, where water is collected in the Schoharie and Ashokan reservoirs; (2) the watersheds of the Bronx and Byram rivers in Westchester County, where the water is stored in Byram and Wampus ponds and in the enlarged Kensico Reservoir; and (3) the Croton River and its tributaries.

Water is collected in the 130-bil. gal. Ashokan Reservoir near Kingston from an area comprising 571 sq.mi. Water from the Schoharie watershed is stored in the Schoharie Reservoir, which is a diverting basin having a capacity of 20 bil.gal. From this reservoir water is conveyed to the Ashokan Reservoir through the Shandaken Tunnel. The Catskill Aqueduct carries the water from Ashokan Reservoir into the Kensico Reservoir, thence into a distribution reservoir at Hillview, Yonkers, from which two tunnels extend through the city for the distribution of the Catskill supply.

Kensico Reservoir, with a flow line elevation of 357 ft. and a capacity of 30 bil.gal., was constructed about 17 mi. north of the city to provide reserve storage for use in the event of an interruption of the supply in the 75 mi. of aqueduct to the north. It is therefore always kept approximately at full capacity. The reservoir serves also as an equalizing basin to take care of fluctuations in demand over short-term periods. The safe or dependable supply which can be obtained from the Catskill watersheds, combined with the watersheds of the Bronx and Byram rivers, which flow into the Kensico Reservoir, is 510 mgd. This dependable supply is that which can be obtained over the driest periods on record and still leave about 25 per cent of the impounded storage in reserve. Under normal conditions of rainfall and run-off, however, water can be drawn upon to the full capacity of the aqueduct between Ashokan and Kensico, which is 620 mgd.

In addition to the two tunnels from Hillview, there is available for transportation of Catskill water from Kensico to the city a 48-in. cast-iron main, known as the Bronx pipeline. This line was originally laid in 1886 to convey water from a small reservoir on the Bronx River, since absorbed into Kensico Reservoir.

The next most important source is the Croton River and its tributaries, the watershed drawn upon comprising an area of 375 sq.mi. above the new Croton Dam. The water is impounded

in twelve storage reservoirs and six controlled lakes, having a total aggregate capacity of 103 bil.gal. The lowest and largest of these reservoirs is Croton Lake, with a flow line at el. 201.50 ft.,* and a capacity of about 34 bil.gal. Water is conveyed from Croton Lake to the city through two adeducts—the New Croton Aqueduct, having a capacity of 295 mgd., and the Old Croton Aqueduct, which had an original capacity of some 90 mgd., but because of its condition the flow therein is now limited to about 35 mgd. The dependable supply from the Croton watershed, on the basis previously defined, is about 315 mgd., which is only slightly less than the combined capacity of the two aqueducts.

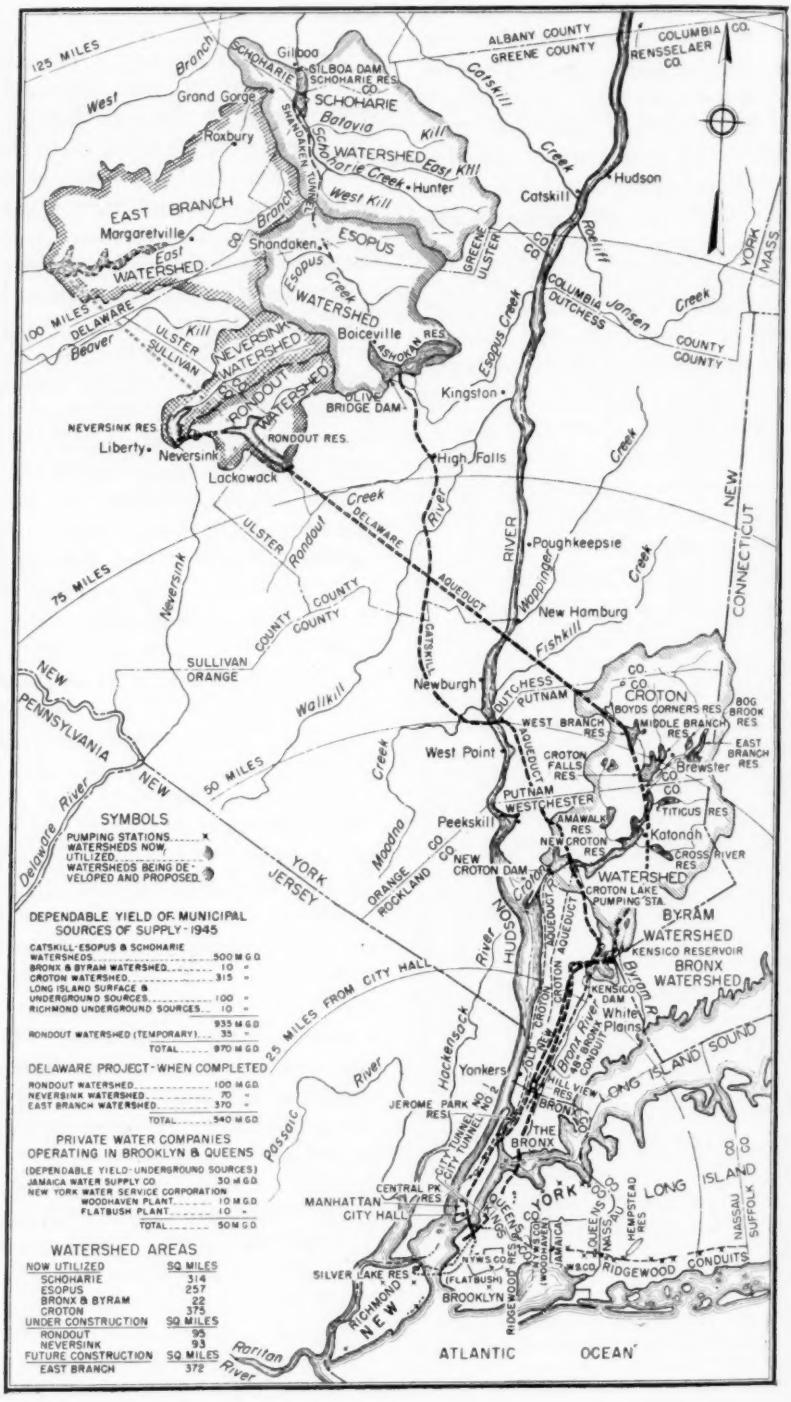
In addition to these upland surface sources, the city can obtain approximately 100 mgd. from the Long Island system, which comprises a number of well plants, infiltration galleries and surface ponds, these constituting part of the water works of the old city of Brooklyn system, upon which that area relied for its entire supply prior to the introduction of Catskill water in 1917. About 10 mgd. can also be obtained from well plants on Staten Island.

Both of the Croton aqueducts and the Bronx pipeline are located entirely within Westchester County, and slightly less than half of the total length of the Catskill Aqueduct (92 mi.) is within the county limits. Kensico Reservoir and its tributary ponds and streams, as well as five of the most important reservoirs on the Croton system, including Croton Lake, are also within the boundaries of Westchester County.

*All elevations mentioned are referred to the Coast and Geodetic datum, mean level at Sandy Hook.

Legal Provisions

Under a law passed by the state legislature about 30 years ago, and now incorporated as Section k41–42.0 of the Administrative Code of the city of New York, the Commissioner of the Department of Water Supply, Gas and Electricity is empowered to issue, and obliged to grant permits to municipal corporations and water districts in the counties of Ulster, Greene, Delaware, Schoharie, Sullivan, Orange, Putnam and Westchester, to make connections to and take water from any of the reservoirs, aqueducts, conduits, streams or pipes of the New York City water supply system. These permits are granted subject to reasonable rules and regulations which will safeguard the city's interests. It is provided that all the work of making these connections shall be at the expense of the permittees and performed in accordance with a plan submitted to and approved by the commissioner, such plan to include the installation of proper meters to measure the quantity of water taken. The law specifies that the communities shall pay to the city such fair and reasonable water charge or rate as may be agreed upon between them. In the event of disagreements the State Water Power and Control Commission is given power to fix such charges, after hearing all parties interested. The law also provides that the daily quantity of water taken by any community shall not exceed that calculated on the basis of the per capita consumption within the city. Payment for the water taken is on a metered basis. Prior to Jan. 1, 1934, the rate for metered water in the city of New York was $1.00 per 1,000 cu.ft., and on that date this was increased a flat 50 per cent, to $1.50 per 1,000 cu.ft. At that time the rate


125 MILES
West Branch
Delaware River
Gilboa
SCHOHARIE
GILBOA DAM
SCHOHARIE RES.
CO.
SCHOHARIE
WATERSHED
Grand Gorge
Roxbury
Batavia Kill
Schoharie Creek
East Khl
Hunter
West Kill
SHANDAKEN TUNNEL
EAST BRANCH
Margaretville
East WATERSHED
Shandaken
ESOPUS
Esopus Creek
WATERSHED
Boiceville
ASHOKAN RES.
ALBANY COUNTY
GREENE COUNTY
COLUMBIA CO.
RENSSELAER CO.
Catskill Creek
Hudson
Catskill
Roeliff Jansen Creek
COLUMBIA
DUTCHESS
COUNTY
COUNTY
YORK
MASS.
GREENE
ULSTER
BIG
100 MILES
DELAWARE
Beaver Kill
ULSTER
SULLIVAN
NEVERSINK WATERSHED
RONDOUT WATERSHED
OLIVE BRIDGE DAM
Kingston
NEVERSINK RES.
Liberty
Neversink
RONDOUT RES.
Lackawack
High Falls
Esopus Creek
Rondout Creek
DELAWARE AQUEDUCT
HUDSON RIVER
Poughkeepsie
Wappinger Creek
New Hamburg
Fishkill Creek
CONNECTICUT
NEW
75 MILES
Neversink
COUNTY
COUNTY
COUNTY
SULLIVAN
ORANGE
Newburgh
DUTCHESS
PUTNAM
CO.
CO.
CROTON
BOYDS CORNERS RES.
BOG BROOK RES.
MIDDLE BRANCH RES.
WEST BRANCH RES.
EAST BRANCH RES.
Brewster
CO.
NEW PENNSYLVANIA
Wallkill
50 MILES
Delaware River
West Point
CROTON FALLS RES.
CROTON AQUEDUCT
PUTNAM
WESTCHESTER
CO.
TITICUS RES.
Peekskill
AMAWALK RES.
NEW CROTON RES.
Katonah
CROSS RIVER RES.
Moodna Creek
ORANGE
ROCKLAND
NEW CROTON DAM
Croton River
WATERSHED
CROTON LAKE PUMPING STA.
YORK
JERSEY
BYRAM WATERSHED
KENSICO RESERVOIR
BRONX WATERSHED
KENSICO DAM
White Plains
Bronx River
BRONX AQUEDUCT
HUDSON RIVER
25 MILES FROM CITY HALL
Hackensack River
Yonkers
HILL VIEW RES.
LONG ISLAND SOUND
JEROME PARK RES.
BRONX
THE BRONX
Passaic
CITY TUNNEL NO. 1
CITY TUNNEL NO. 2
CENTRAL PK RES.
MANHATTAN
CITY HALL
QUEENS CO.
NASSAU CO.
HEMPSTEAD RES.
LONG ISLAND
NASSAU
SUFFOLK
SILVER LAKE RES.
RICHMOND
NEW
(FLATBUSH)
BROOKLYN
RIDGEWOOD RES.
RIDGEWOOD
CONDUITS
Raritan River
ATLANTIC OCEAN
SYMBOLS
PUMPING STATIONS
WATERSHEDS NOW UTILIZED
WATERSHEDS BEING DEVELOPED AND PROPOSED
DEPENDABLE YIELD OF MUNICIPAL SOURCES OF SUPPLY - 1945
CATSKILL-ESOPUS & SCHOHARIE WATERSHEDS 500 M G D
BRONX & BYRAM WATERSHED 10 "
CROTON WATERSHED 315 "
LONG ISLAND SURFACE & UNDERGROUND SOURCES 100 "
RICHMOND UNDERGROUND SOURCES 10 "
935 M G D
RONDOUT WATERSHED (TEMPORARY) 35 "
TOTAL 970 M G D
DELAWARE PROJECT - WHEN COMPLETED
RONDOUT WATERSHED 100 M G D.
NEVERSINK WATERSHED 70 "
EAST BRANCH WATERSHED 370 "
TOTAL 540 M G D.
PRIVATE WATER COMPANIES OPERATING IN BROOKLYN & QUEENS
(DEPENDABLE YIELD - UNDERGROUND SOURCES)
JAMAICA WATER SUPPLY CO. 30 M G D.
NEW YORK WATER SERVICE CORPORATION
WOODHAVEN PLANT 10 M G D.
FLATBUSH PLANT 10 "
TOTAL 50 M G D.
WATERSHED AREAS
NOW UTILIZED SQ. MILES
SCHOHARIE 314
ESOPUS 257
BRONX & BYRAM 22
CROTON 375
UNDER CONSTRUCTION SQ. MILES
RONDOUT 95
NEVERSINK 93
FUTURE CONSTRUCTION SQ. MILES
EAST BRANCH 372

charged for water taken by the outside communities was 50¢ per 1,000 cu.ft. for Croton water and 75¢ per 1,000 cu. ft. for Catskill water. These rates were not changed at the time the city rates were increased. On Dec. 1, 1938, however, the rates to the outside communities were increased by 5 per cent, the charge being fixed at 52½¢ per 1,000 cu.ft. for Croton water and 78¾¢ per 1,000 cu.ft. for Catskill water, effective for a five-year period, to Dec. 1, 1943. These rates have since been continued for an additional three-year period, until Dec. 1, 1946. The rates are based on the fixed charges and expenses of maintenance and operation of the water system outside of the city limits. These rates are believed to be reasonable, and no community has to date asked for their review by the State Water Power and Control Commission.

Water Taken by Outside Communities

In accordance with these legal provisions, twenty permits have been issued to communities to take water from the Catskill Aqueduct in Westchester County, one in Putnam County, and four to communities west of the Hudson River. The city of New Rochelle and the village of North Tarrytown were issued permits for connections to take water from the New Croton Aqueduct. The city of White Plains, the village of Scarsdale and a small water district normally take water from the Bronx pipeline; Sing Sing Prison and the villages of Ossining, Briarcliff Manor and Irvington obtain a supply from the Old Croton Aqueduct; and some seven Westchester communities obtain their supply through connections to reservoirs.

In addition, the cities of Yonkers and Mount Vernon have jointly constructed a 48-in. pipeline connecting to Hillview Reservoir; Mount Vernon thus obtains its entire supply, while Yonkers substantially supplements its own source.

Where the distribution system is owned and operated by a private water company, a permit is granted to the community, which designates the company as its agent for the distribution of water, but the bills are rendered to the communities, and they are responsible for payment.

During the year 1944 the total amount of city water taken by all the outside communities averaged 26.5 mgd., practically all of which was consumed in Westchester County. This was a marked increase over 1943, during which the average taken was 21.6 mgd. The average consumption within the city limits for 1944 was 939 mgd. from the municipal system. An additional 65 mgd. was supplied by two private water companies which obtain their water from wells.

The principal outside consumers served and the amount of water taken by them were: the city of New Rochelle and adjacent communities, which took 8.8 mgd. from the New Croton Aqueduct; the city of Mt. Vernon, which drew 4.9 mgd. from the Hillview Reservoir; the city of White Plains, which took 2.11 mgd. from the Bronx pipeline; the city of Yonkers, which drew 5.30 mgd. from the Hillview Reservoir and a connection to the Catskill Aqueduct; the village of North Tarrytown, which drew 0.96 mgd. from the New Croton Aqueduct; and the Westchester Joint Water Works District No. 1, supplying Mamaroneck, Harrison and adjacent sections, which drew 0.77 mgd., from the Kensico

Reservoir. All the other communities are small, and the amount of water taken by them varied from only a few thousand gallons up to a possible 300,000 gpd. It is estimated that of a total population of 580,000 in Westchester County, some 260,000, or about 45 per cent, depend on the New York City system for water.

With one exception, hereafter mentioned, all the water taken by these communities is pumped by them, since the elevation of the hydraulic gradient in the city conduits is too low to supply the areas by gravity.

The connections to the aqueducts are suction pipes, usually inserted in openings just above the invert or cut through the top of the arch, and extended to adjacent pumping stations. Several connections to the Catskill Aqueduct were made to supply pipes inserted just above the invert at the time of its construction, but these were found to be inadequate in number, or not suitably located, and new connections had to be cut, generally through the top of the aqueduct, to avoid shutdowns. Several connections have also been made to blow-off pipes, manholes, etc.

Delaware-Rondout Project

Since the consumption of water within the city, together with that supplied to outside communities, has at times been close to or even exceeded the dependable supply of 935 mgd. from the sources previously mentioned, in 1937 the city commenced work on a project to secure an additional supply of water from Rondout Creek, a tributary of the Hudson; the East Branch of the Delaware River; and the Neversink River, a tributary of the Delaware.

The first stage of this project includes the development of the Rondout and Neversink watersheds. The Merriman Dam to be constructed on the Rondout Creek, near Lackawack, N.Y., will impound the Rondout Reservoir with a capacity of 50 bil.gal.; and a dam impounding a reservoir of 30 bil.gal. will be constructed on the Neversink River in the village of Neversink. Water from the Neversink Reservoir is to be conveyed to the Rondout Reservoir by a short tunnel. The combined area of these two watersheds is 165 sq.mi., from which an estimated safe yield of 170 mgd. can be obtained.

The second stage of the project involves the construction of a dam on the East Branch of the Delaware near Downsville, N.Y., impounding a reservoir having a capacity of 147 bil.gal. A tunnel about 26 mi. long will convey the water from the East Branch Reservoir to the Rondout Reservoir. This will provide an additional supply of 370 mgd., making a total of 540 mgd. for the entire project.

As part of the first stage, there is included the construction of the Delaware Aqueduct, a deep pressure tunnel some 85 mi. in length, which delivers water from the Rondout Reservoir into the West Branch Reservoir of the Croton system, thence into Kensico Reservoir and finally into the Hillview Reservoir, from which distribution will be effected in the same manner as for Catskill water.

It was anticipated that the work on the first stage would be completed some time during the middle of 1945, but because of war conditions it was necessary to suspend all work on the construction of the Merriman Dam, Rondout Reservoir and the Neversink project, in 1941. Fortunately, the Delaware Aqueduct was near enough

completion early in 1942 to permit emergency operation.

With the easing of wartime restrictions on materials and manpower it is expected that the New York Board of Water Supply will resume work on the Delaware-Rondout project sometime later this year, but it will take at least four years after such work is started to complete the equipping and testing of the Delaware Aqueduct so that it can be safely and continuously operated, and to complete the Merriman Dam, Rondout Reservoir and appurtenant works. It will be at least two years more before the Neversink Dam, tunnel and appurtenant works are made available, and the completion of the entire project, including the East Branch works, can hardly be anticipated before 1953 or 1954. All of this work is being carried on by the Board of Water Supply and as the various sections are completed they will be turned over to the Department of Water Supply, Gas and Electricity for maintenance and operation.

Use of Delaware Aqueduct

The section of the Delaware Aqueduct between Kensico and Hillview reservoirs was placed in operation in March 1942, thereby safeguarding the vital section of the Catskill Aqueduct between these two reservoirs, and also providing additional capacity for the delivery of water from Kensico Reservoir to the city. The section between Kensico and West Branch reservoirs was placed in operation a year later, on Mar. 3, 1943, and, although this did not increase the water available to the city, it was a valuable addition to the system.

It made available the runoff from 43 sq.mi. of Croton watershed above West Branch Reservoir, for delivery into Kensico, thus making possible the use of this high-level source to the extent of 40 to 50 mgd. in all boroughs of the city, without pumping.

The available capacity of the two impounding reservoirs, West Branch and Boyds Corners, on the West Branch watershed, for delivery into Kensico, is about 7 bil.gal. This was a valuable addition to the reserve storage in Kensico Reservoir for use in emergencies.

The works completed at the Rondout site included the diversion tunnel under the dam and the channel below it and, pending the completion of the dam and reservoir, the Board of Water Supply constructed a short tunnel from this channel into an adjacent shaft of the Delaware Aqueduct, diverting the stream flow of Rondout Creek into it.

On Mar. 5, 1944, Mayor La Guardia formally opened the gates on this temporary tunnel and started the flow into the West Branch Reservoir. As this is a stream flow without benefit of storage, it is subject to wide variations, the delivery into West Branch having ranged from as high as 350 mgd. in the spring months to as little as 7 mgd. in summer. The average delivery during the past year was 72 mgd. It is estimated that the safe yield from the combined West Branch and Rondout watersheds over the driest period would be about 75 mgd., of which about 35 mgd. would be from the Rondout watershed, this constituting the net increase to the dependable supply of the city's sources obtained by the Rondout diversion.

The operation of the Delaware Aqueduct is being carried on by the Board of Water Supply in accordance with the requirements of and in co-operation with the Department of Water Supply, Gas and Electricity. This

operation is of a temporary and emergency nature; the control of the inlets at the gatehouses of West Branch and Kensico reservoirs is by means of movable stop shutters inserted in stop plank grooves, pending the installation of the permanent sluice gates.

Operation of System

In the operation of the system the various sources, as previously described, are utilized in the order of their relative economy. The high-level sources comprise the water entering Kensico Reservoir, which includes the flow in the Catskill Aqueduct from the Ashokan Reservoir and that in the Delaware Aqueduct from West Branch Reservoir, including the Rondout delivery; and the runoff from the watershed of Kensico itself. The water from Kensico is delivered through the Catskill and Delaware aqueducts into Hillview Reservoir, el. 295 ft., and practically all of this can be distributed throughout the city by gravity.

The water delivered through the two Croton aqueducts, up to their capacity of 325 mgd., reaches the city at the elevation of Jerome Park Reservoir (133 ± ft.) and only about 140 mil. gal. of this can be distributed by gravity in the low-lying areas; the remainder must be pumped by several electric, steam and hydraulic plants within the city, this pumpage supplementing the Catskill supply to the higher ground.

The Long Island sources are the most expensive, pumping being required twice, and in some instances, three times. These sources are utilized only when the storage in the up-state reservoirs is deficient.

The Rondout and West Branch water, delivered through the Delaware Aqueduct, is utilized to the fullest extent possible because of the present inadequate storage in these watersheds. At times, when the storage in the Ashokan Reservoir is below capacity, the use of water in volume from West Branch enables the draft on the Ashokan to be reduced. Thus Catskill storage can be built up to the fullest possible extent, for use during the long summer period of heavy drawdown. When the Ashokan Reservoir is full and a heavy draft is also possible from the West Branch and Rondout sources, no Long Island water is used and the pumping of Croton is reduced to a minimum, thereby effecting substantial economies in operation.

During the summer season, after the peak of storage has been passed, the demand on this system averages well over 1,000 mgd. and frequently reaches 1,100 mgd., necessitating the use of both the Catskill and Croton aqueducts at their full capacity of about 940 mgd. The deficiency is made up by drawing on the West Branch storage and the Rondout delivery, and when West Branch becomes depleted in the fall and there is continued high consumption, it is necessary to do a certain amount of pumping on Long Island. Otherwise there would be an excessive depletion in Kensico Reservoir.

In this connection an incident might be mentioned here which will be of interest to outside communities taking water from the city system. In the latter part of April 1944, shortly after the Rondout water became available, the storage in the Catskill Reservoirs was about 35 bil.gal. below capacity. During this period there was available for delivery through the Delaware Aqueduct, from the West Branch and Rondout, about 250 mgd., and, in line with the method of operation above outlined, in order to build up the Ashokan Reservoir storage, the de-

livery into the Catskill Aqueduct was reduced to 250 mgd. This figure is equivalent to a depth of about 6½ ft. in the aqueduct, the height of the cut and cover section being 17 ft. No trouble was experienced by the outside communities because of this reduction, since the suction pipes connecting to the aqueduct were only 2 or 3 ft. above the invert. An exception was the case of one water district, which has a connection to the Catskill Aqueduct north of Kensico and supplies an average of 80,000 gpd. to several villages along the Hudson. This district had attached a 16-in. pipe to one of the town connections placed by the Board of Water Supply, the center of this pipe being about 2 ft. above the invert. The district also laid a 16-in. main several miles in length, from the aqueduct to the areas to be served. The elevation of the aqueduct here is at a level which would make possible the supply of these areas entirely by gravity, and, in fact, the pressure is so excessive as to require its reduction for distribution in the system. Although a depth of 6½ ft. in the aqueduct should be adequate to maintain a satisfactory supply, trouble was experienced, and no water was available, due possibly to unsatisfactory hydraulic conditions in the long pipeline. The district contended that a minimum of 8½ ft. would be required to maintain a satisfactory flow. It was manifestly not reasonable, with the condition of the reservoirs as described, to require the city to increase the flow in the aqueduct by 125 mgd. and have an equivalent amount of water flow over the spillway at the West Branch Reservoir into the lower reservoirs of the Croton system from which it could only be utilized by pumping, for the sole benefit of a community taking about 80,000 gpd. from the aqueduct. The district was advised to make a survey of the pipeline and correct the hydraulic conditions, or install a low-lift pump which could be operated at times when the water in the Catskill Aqueduct was flowing at a depth of less than 8½ ft. That the method of operation followed by the city was proper was later indicated by the fact that the Catskill reservoirs did not fill up during 1944, the maximum storage reached being nearly 10 bil.gal. below capacity. It might be stated that the district was not deprived of water during the period of low flow in the aqueduct, which lasted for several weeks, since it obtained a supply from an adjacent community, although at a somewhat higher cost.

This incident brings up the question of flows to be maintained in existing aqueducts for the needs of the communities connected thereto, after the Delaware Aqueduct has been placed in permanent and continuous operation, and when the additional supplies of water from the new sources become available. The amount of flow in the aqueducts will depend on the storage conditions in the respective watersheds, and the demand on the system at the time. Although the author is not in a position to speak for future administrative and operating officials of the water department, it may be assumed that the flows in the Catskill and Croton aqueducts will be maintained to provide adequate service to the communities connected to them, except, of course, during periods of shut-down.

The Catskill Aqueduct has now been in service for more than 30 years. It has never been shut down for a period exceeding 24 hours, and this was only in the northerly sections. After the Delaware Aqueduct and new sources

become available it will be possible to shut down the Catskill Aqueduct for inspection, cleaning and minor repairs which have been deferred because of the need of maintaining it in continuous service. While a shut-down of the Catskill Aqueduct can be made by sections so that all the communities will not be deprived of water at the same time, sooner or later all will be affected. Such shut-downs will probably last for some time, and may also be made on the Croton Aqueducts, for the purposes above stated. It would therefore be very desirable for these communities to obtain alternate means of supply, either from the Delaware Aqueduct, or from some other sources.

It is the author's understanding that many of these communities have installed connections for the interchange of water between their systems, and that, while full data on the subject are not available, these facilities have been expanded under the Mutual Aid Program (see page 736, this JOURNAL) during the war emergency.

Recognizing the present and future needs of the upstate communities, and the possibilities of a shut-down of the existing aqueducts, the Board of Water Supply, in the design of the Delaware Aqueduct, has provided means for connections thereto. Since this is a deep-pressure tunnel for its entire length, no direct connections can be made to it, as is possible on the other conduits. The board has therefore provided a number of shafts which have risers surmounted by caps on which there are outlets. Pipe connections may thus be made between these outlets and the mains of adjacent water systems. These shafts are also equipped with riser plug valves, so that they can be individually shut off without affecting the aqueduct as a whole.

The following are the locations of shafts in Westchester County which are to be equipped so that connections can be made thereto by communities.

North of Kensico Reservoir

Shaft 11, just south of Croton Falls Dam
Shaft 13, in Katonah

South of Kensico Reservoir

Shaft 20, at Knollwood Road, Town of Greenburgh
Shaft 21, at Underhill Road, Town of Greenburgh
Shaft 22, at Crisfield Street, Yonkers
Shaft 23, at Palmer Road, Yonkers

Similar equipment has been installed for this purpose in Shaft 6, at Fishkill, and Shaft 5A, just west of the Hudson River.

No connection can be made to these shafts until certain valves and other appurtenances have been installed thereon, this being part of the work still to be done for testing and equipping the aqueduct, previously mentioned, and until such work is completed and the aqueduct turned over to the Department of Water Supply, Gas and Electricity for operation, the commissioner of that department cannot entertain applications for connections.

The four shafts below Kensico are located within the more populated areas of Westchester County, and the distance between the Catskill and Delaware aqueducts here varies only about from 3,000 to 5,000 ft.

In the case of small communities or water districts, the cost of making long connections to the Delaware Aqueduct and extending new mains in their territories may be excessive, but it should be possible for several of these communities jointly to install one connection to be utilized by all. It might be well to have all the communities in

Westchester County taking water from the Catskill or Croton Aqueducts establish a joint committee of engineers to study this matter within the next few years, with a view to utilizing the Delaware Aqueduct as an alternate or emergency source of supply to the best advantage and at a minimum cost. This committee might also study and make recommendations with respect to providing additional connections between the various systems for emergency interchange of water between them. The city agencies would be glad to co-operate in finding the best solution of the problem.

Bronx Pipeline

Since the construction of City Tunnel No. 2, which extends from Hillview Reservoir along the easterly part of the Bronx, and the placing in service of the section of the Delaware Aqueduct between Kensico and Hillview, the Bronx pipeline is of no value in the city's water supply system, and is now maintained solely to provide a supply to the several communities connected to it. Of these only White Plains and the North Castle Water District No. 1 take water continuously through connections which are only about 2 mi. below Kensico Dam.

New Rochelle, Yonkers, Mount Vernon and Scarsdale have connections which are used only in emergencies, since they can obtain water from other connections to the city system. In order to eliminate the expense of maintenance and operation of this long line, consideration is being given by the city to capping the main about 2 mi. south of Kensico Dam, the use of the rest of the line to be discontinued.

Treatment of Supply

The Catskill water is aerated and chlorinated as it enters the aqueduct at Ashokan Reservoir, again aerated and treated with chlorine at the point where it enters the aqueduct at Kensico Reservoir and, finally, chlorinated as it enters the two distribution tunnels at Hillview.

Croton water is chlorinated as it enters the new aqueduct at Croton Lake, and again at Dunwoodie, just north of the city line. The water in the Old Croton Aqueduct is also treated at Dunwoodie, and again at the 135th Street Gatehouse, Manhattan, where it enters the distribution system.

The water in the Bronx pipeline is chlorinated at Kensico Dam.

Because of the existence of clay banks in the Schoharie watershed, the Catskill water becomes turbid at times to such an extent that treatment for the removal of this turbidity is required. Treatment is started when the turbidity reaches 9 on the silica scale, which is infrequent, and is effected by adding alum at a plant on the Catskill Aqueduct at Pleasantville and lime at a plant just above the influent gatehouse at Kensico Reservoir. This process has not been necessary for the past four years.

From the method of treatment as outlined, it is evident that the consumers in communities having connections north of Kensico take water which has been chlorinated only once, while the water south of Kensico receives a double chlorination. Also, consumers in communities which have connections north of Pleasantville get water which has not had the benefit of turbidity treatment. The permits granted to communities outline the normal treatment which is given to the water at the proposed point of connection, but the city does not assume responsibility for the quality of the

supply, or for continuous treatment, since it is liable to interruption by contingencies beyond its control. The communities are obliged to install at their own cost such additional facilities for chlorination and turbidity or other treatment as they may deem desirable, or as may be required by the state and county departments of health.

On the Delaware system, a temporary plant has been installed at the influent gatehouse at Shaft 17, Kensico Reservoir, which chlorinates all the water delivered into that reservoir from West Branch Reservoir, including the Rondout supply.

Eventually, it is planned to chlorinate the water as it enters the Delaware Aqueduct at the Rondout Reservoir, again when it enters the aqueduct at the gatehouse at Shaft 10, West Branch, and finally, at the effluent gatehouse at Kensico Reservoir, Shaft 18.

Provision has been made for the treatment of turbidity for the entire Delaware supply at the influent gatehouse at Shaft 17, Kensico.

The Catskill is a very soft water, having a hardness of about 19 ppm., a low alkalinity of 10 ppm., and a pH of 6.7; the total solids average only 39 ppm. Because of these characteristics it is quite corrosive, and for over 25 years the department has specified that all of its cast-iron pipe be cement lined, and recommends that communities taking Catskill water adopt similar specifications. Analyses of the Rondout and Delaware waters indicate that their chemical characteristics are very similar to those of Catskill water. Croton water is not quite so soft, its average hardness being about 49 ppm., alkalinity 29 ppm., pH 7.0 and total solids 80. An inspection of pipe carrying Croton water for 50 years indicates only moderate tuberculation.

At present the water entering Kensico Reservoir from West Branch has a hardness averaging 29 ppm. and an alkalinity of 18 ppm. This is due to the admixture of Croton water. When the full amount of Delaware water becomes available, the comparatively small percentage of Croton water mixed with it will not affect its main characteristics, as described.

Gradients and Pressures in Delaware Aqueduct

Although the flow line of the Rondout Reservoir will be at el. 840 ft., as compared with el. 590 ft. for Ashokan Reservoir, and the Delaware Aqueduct is a pressure tunnel, the elevation of the hydraulic gradient at the shafts of the Delaware Aqueduct in Westchester County, to which connections can be made by communities, will not be appreciably higher than those along the Catskill Aqueduct. The reason for this is that the Delaware Aqueduct is also operated in conjunction with the Kensico and Hillview reservoirs, and the flow line elevations of these reservoirs determine the elevations of the hydraulic gradient along the Delaware Aqueduct, on the respective sections. The elevations of the hydraulic gradients at Shafts 20, 21, 22 and 23 will be about the same as those in the Catskill Aqueduct, being influenced by Hillview. The elevations of the hydraulic gradients at Shafts 11 and 13 will be possibly 4 or 5 ft. higher, being controlled by the elevation of the inflow weir at Shaft 17, Kensico, which is 361 ft. However, the elevations of the hydraulic gradients at Shafts 5A and 6 will be much higher than those of the Catskill Aqueduct, since they are influenced by the elevation of the inflow at Shaft 9 into West Branch Reservoir, which is 511 ft.

St. Marys, Pennsylvania—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1941

THE St. Marys Water Co. is a privately-owned water company serving the Borough of St. Marys and surrounding territory in Elk County in the northwestern section of Pennsylvania. The 1940 population of the borough was 7,653.

St. Marys is primarily an industrial community. It is east of the main producing oil fields but natural gas occurs in the vicinity and is piped throughout the borough. It is slightly north of the bituminous coal fields but there are important mines some 5 mi. south. The important industries in St. Marys are the manufacture of clay products, such as brick, fire brick, tile and sewer pipe; tanneries; a foundry; an incandescent lamp factory and two concerns manufacturing carbon products.

It is located on the top of the divide between the Allegheny and Susquehanna watersheds and it is necessary to pump the entire supply uphill to the borough.

As of the date of this study there were 1,976 consumers serving approximately 8,200 people within and without the borough limits. Water delivered to the system during 1941 averaged 0.8 mgd. or about 98 gpd. per capita. Of this amount about 49 per cent was served to the industries.

Development of the Existing System

The St. Marys Water Co. was incorporated in 1889 and has been owned and operated as a private system under several owners. The company was acquired by the Community Water Service Co. in 1928, the controlling interest in which passed to the American Water Works & Electric Co., Inc., in 1936.

The company secures its supply from four sources located in different directions from the borough. Three of these sources are surface supplies, augmented at times from wells at each location, and the fourth source is a well supply less frequently operated.

Silver Creek Supply

The first source of supply, developed in 1889, was the Silver Creek supply, obtained at a small intake dam of timber construction on Silver Creek about 2 mi. northwest of St. Marys. This creek has a gentle rolling watershed area of 1.54 sq.mi. at the intake. The original source was pumped by a steam plant which was abandoned in 1926. The surface supply is augmented from wells, the first well being drilled in 1895. Seven additional wells have been added over the years.

Laurel Run Supply

The second supply, Laurel Run, was developed in 1898 and is obtained about 3 mi. south of St. Marys from a watershed area of 1.7 sq.mi. A small reservoir, impounding from 2 to 3 mil.gal., is formed by a small concrete dam. Seven wells have also been drilled to augment the surface supply.

TABLE 1

SUMMARY OF MAINS

ST. MARYS, PENNSYLVANIA

Size, *in.*	Kind	No. of Feet Installed	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percentage of Total	Year of First Installation	Average Age, *yr.*
1	Wrought-iron	305	0.2	0	0	305	0.2	1900	41.5
1¼		1,395	0.8	750	7.2	645	0.4	1900	35.5
1½		261	0.1	0	0	261	0.1	1900	41.5
2		6,242	3.4	3,994	38.2	2,248	1.3	1898	38.1
4		6,309	3.4	4,619	44.2	1,690	1.0	1889	43.5
5		876	0.5	0	0	876	0.5	1900	43.5
6		22,969	12.4	511	4.9	22,458	12.8	1897	42.6
4	Cast-iron unlined	64,543	34.8	571	5.5	63,972	36.6	1891	36.0
6		26,781	14.4	0	0	26,781	15.3	1891	35.9
8		23,481	12.7	0	0	23,481	13.4	1907	34.5
2	Cast-iron cement-lined	9,800	5.3	0	0	9,800	5.6	1931	2.6
4		1,422	0.7	0	0	1,422	0.8	1931	6.1
6		10,774	5.8	0	0	10,774	6.2	1928	8.1
8		10,107	5.5	0	0	10,107	5.8	1927	14.5
TOTAL		185,265	100.0	10,445	100.0	174,820	100.0		31.7
Percentage of Total		100.0		5.6		94.4			
Average Size, *in.*		5.18		3.14		5.30			

Mortality Survival Ratios

Size, *in.*	Kind	No. of Feet	Period Covered, *yr.*	Percentage
1–1½	Wrought-iron	1,961	41.5	61.754
2–6		36,396	44.5	74.174
4	Cast-iron unlined	64,543	50.5	98.028
6		26,781	50.5	100.000
8		23,481	34.5	100.000
2	Cast-iron cement-lined	9,800	10.5	100.000
4		1,422	10.5	100.000
6		10,774	13.5	100.000
8		10,107	14.5	100.000
	TOTAL	185,265		

Wolf Lick Run Supply

The Wolf Lick Run supply is obtained from a rugged, mountainous watershed of 3.28 sq.mi. in an area located about 5 mi. southeast of St. Marys. The reservoir, with a capacity of 8.5 mil.gal., is formed by a combination concrete and earthen dam with concrete spillway and wasteway.

This source, presently the largest and most important and the third in time of development, was put into service in 1908. As with the other sources, wells are also located here and are used at times.

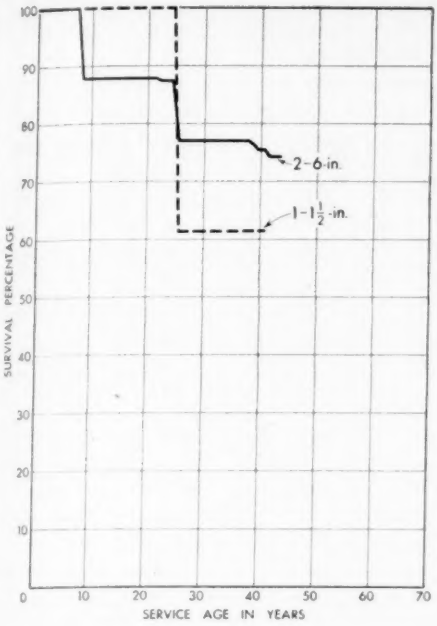


FIG. 1. Mortality Survival Curve—1–6-in. Wrought-Iron Mains—St. Marys, Pa., Water Co.

BASE: Feet	SURVIVAL: 1899–1940	
SIZE	EXPOSURES	RETIREMENTS
in.	*ft.*	*ft.*
1–1½	1,961	750
2–6	36,396	9,124

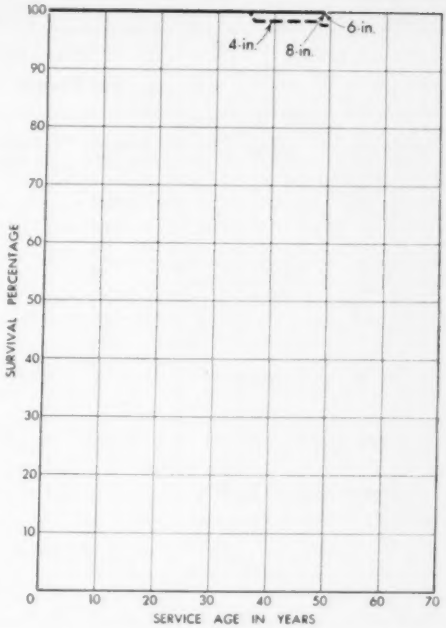


FIG. 2. Mortality Survival Curve—4–8-in. Cast-Iron Unlined Mains—St. Marys, Pa. Water Co.

BASE: Feet	SURVIVAL: 1891–1940	
SIZE	EXPOSURES	RETIREMENTS
in.	*ft.*	*ft.*
4	64,543	571
6	26,781	0
8	23,481	0

Luhring Pines Supply

This supply is secured from wells located about 2 mi. north of the eastern end of the borough. It was developed in 1926 and 1927 and is generally used only when the surface and well supplies at the other three sources are inadequate. Six wells, pumped by air lift, discharge into an open, circular, reinforced concrete collecting basin with a capacity of 100,000 gal. The basin also serves as a suction well for the pumps.

The wells located at the several sources are generally 6 and 8 in. in diameter, from 100 to 300 ft. deep, cased for from 20 to 30 ft. in depth and all pumped by air lift.

No treatment other than chlorination is given at any of the supply points. Small pumping stations housing natural gas, engine-driven triplex pumps for high-lift and air compressors for air-lift pumping of wells are located at each supply point. They pump the supply to distribution reservoirs or to the system.

From the Silver Creek supply a 6-in. black wrought-iron pipeline, 4,390 ft. long, laid in 1889, extends to the North Michael Reservoir.

TABLE 2

SUMMARY OF METERS
ST. MARYS, PENNSYLVANIA

Size, *in.*	Kind	Number Installed	Number Identified	Number Retired	Number in Service	Average Age, *yr.*
$\frac{5}{8}$	Disc	1,989	1,841	258	1,583	12.2
$\frac{3}{4}$		112	83	18	65	14.0
1		28	28	8	20	8.6
$1\frac{1}{4}$		7	7	1	0	27.8
$1\frac{1}{2}$		14	7	3	4	4.5
2		15	9	5	4	6.5
3	Current	14	13	3	10	10.8
4		2	2	1	1	9.5
6		1	1	0	1	23.5
TOTAL		2,182	1,991	297	1,694	12.3
Percentage of Total			100.0	14.9	85.1	

Mortality Survival Ratios

Size, *in.*	Kind	Number Identified	Period Covered, *yr.*	Percentage
$\frac{5}{8}$	Disc	1,841	18.5	75.949
$\frac{3}{4}$–6	All	150	32.5	23.295
TOTAL		1,991		

TABLE 3

SUMMARY OF HYDRANTS
ST. MARYS, PENNSYLVANIA

Size, *in.*	Number Installed	Number Retired	Number in Service	Average Age, *yr.*	Mortality Survival Ratio, %
4	91	18	73	27.6	61.579
Percentage of Total	100.0	19.8	80.2		

From the Laurel Run supply a 6-in. black wrought-iron pipeline, 15,200 ft. long, laid in 1898, extends to the South Michael Reservoir.

The Wolf Lick supply is pumped to the South Michael Reservoir through an 8-in. cast-iron main, 23,390 ft. long, laid in 1907.

The Luhring Pines supply is pumped directly to the distribution system through an 8-in. cast-iron line, 10,165 ft. long, laid in 1926.

The North Michael Reservoir, constructed in 1919, is a covered, circular, reinforced-concrete basin, 67 ft. in diameter by 21 ft. deep, holding 500,000

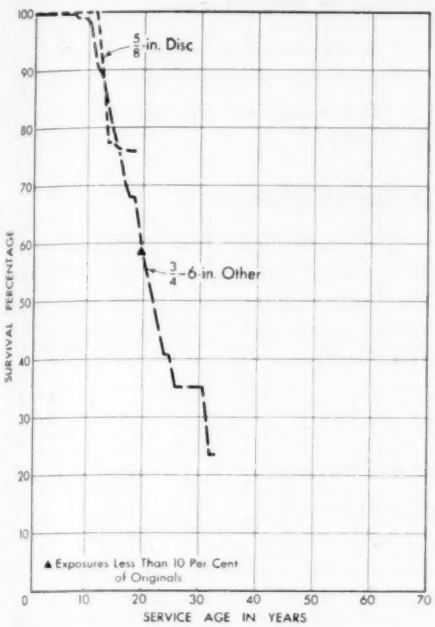


FIG. 3. Mortality Survival Curve—⅝-6-in. Meters—St. Marys, Pa., Water Co.

BASE: Unit SURVIVAL: 1905–1937

SIZE *in.*	KIND	EXPOSURES	RETIREMENTS
⅝	Disc	1,841	258
¾–6	Other	150	39

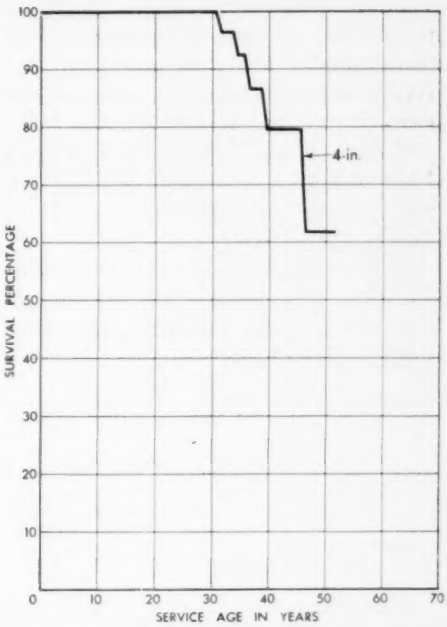


FIG. 4. Mortality Survival Curve—4-in. Hydrants—St. Marys, Pa., Water Co.

BASE: UNIT SURVIVAL: 1889–1940

SIZE *in.*	EXPOSURES	RETIREMENTS
4	91	18

gal. and divided into two parts having separate connections.

The South Michael Reservoir, constructed in 1911, is a square, open, earth embankment reservoir, concrete lined, having a capacity of 2 mil.gal.

The pipe system totals about 33 mi. to which are attached 1,976 services, originally largely galvanized wrought iron, but from 1928 to 1936 cement-lined wrought iron and from 1936 to date copper tubing. Almost all services are metered and account for approximately 78.5 per cent of the water served to the system.

Basis of Study

The records of installation and retirement of pipe and hydrants are substantially complete from the formation of the company to date. The record of installation and retirement of meters through 1937 only is presented herewith.

Mortality Survival Study

Mortality studies were made of mains, meters and hydrants. Table 1 is a summary of the pipe installed, the amount retired and that still in service.

as well as average ages, length of record and other pertinent data. Figures 1 and 2 show the mortality survival curves covering the amount and sizes of pipe grouped as shown.

Tables 2 and 3 and accompanying Figs. 3 and 4, represent similar data and curves covering meters and hydrants, respectively.

A brief summary of Class B facilities covering impounding and distribution reservoirs, wells and pumping equipment is given below.

Causes of Retirement

There exists no complete record from which could be determined the causes of retirement of mains, meters and hydrants.

Acknowledgments

The collection and compilation of data pertaining to the St. Marys Water Co. were carried out by the personnel of the American Water Works & Electric Co., Inc.

Summary of Class B Facilities

St. Marys, Pennsylvania

Impounding Reservoirs

Silver Creek Reservoir—Timber crib dam, maximum height 5 ft., length 24 ft.; impounding 0.15 mil.gal. Constructed in 1889; still in service.

Wolf Lick Reservoir—Concrete, stone and earth dam, maximum height 30.3 ft., length 200 ft.; impounding 8.5 mil.gal. Constructed in 1906–1907; still in service. Timber spillway replaced by concrete in 1916.

Laurel Run Reservoir—Concrete dam, maximum height 8 ft., length 185 ft.; impounding 2.4 mil.gal. Constructed in 1904; still in service. Original dam of timber constructed in 1898 replaced with concrete dam in 1904.

Distribution Reservoirs

South Michael Reservoir—Original timber construction reservoir, covered, partly in cut; 30 ft. wide by 80 ft. long by 8 ft. deep; capacity 0.10 mil.gal. Constructed in 1898; replaced by new reservoir in 1912. Two similar reservoirs were constructed in 1902 and also retired in 1912 by the construction of the new reservoir. The existing South Michael Reservoir was constructed in 1912 and is still in service. It is of earth embankment, uncovered, with concrete lining, 117 ft. square at bottom, 162 ft. square at top, 14 ft. deep; capacity 2.0 mil.gal.

North Michael Reservoir—Covered, reinforced concrete reservoir, 67 ft. in diameter, 21 ft. deep; capacity 0.50 mil.gal. Constructed in 1919; still in service.

Luhring Pines Basin—Open, reinforced concrete with earth backing, receiving and suction basin; 50 ft. in diameter by 7 ft. deep; capacity 0.10 mil.gal. Constructed in 1926; still in service.

Wells

Silver Creek

Number	Year Drilled	Size *in.*	Depth *ft.*	Cased
1*	1894	6	120	25
2	1902	8	150	24
3	1902	8	150	24
4	1903	8	257	25
5	1914	8	142	25
6	1914	8	79	25
7	1914	8	174	25
8	1914	8	176	25

* Abandoned because pump room extended over well.

Laurel Run

1	1902	8	55	25
2	1909	8	174	25
3	1903	8	198	25
4	1903	8	181	25
5	1909	8	203	25
6	1909	8	171	25
7	1914	8	204	25

SUMMARY OF CLASS B FACILITIES (contd.)

Wells (contd.)

Wolf Lick Run

Number	Year Drilled	Size *in.*	Depth *ft.*	Cased
1	1908	6	112	25
2	1908	8	94	25
3	1908	8	119	25
4	1909	8	278	25
5	1909	6	106	25
6	1909	6	117	25
7	1925	6	107	25

Luhring Pines

1	1926	6	172	16
2	1926	6	171	17
3	1926	6	203	24
4	1926	6	163	14
5	1926	6	130	22
6	1926	6	130	23

Pumping Equipment

Silver Creek

Type	Capacity *mgd.*	Year Installed
Plunger, no details * Gas engine	—	1901

* Retired 1927 when new station built. Salvaged for $50.

Pumping Equipment (contd.)

Steam pump and boiler †	—	1889
Plunger pump, 10″ × 10″ 50-hp. gas engine	0.573	1915
Air compressor, 10″ × 18″ 40-hp. gas engine	—	1914

Laurel Run

Type	Capacity *mgd.*	Year Installed
Plunger pump, 9″ × 16″ 100-hp. gas engine	0.685	1904
Plunger pump, 8″ × 10″ 75-hp. gas engine	0.576	1898
Air compressor, 11″ × 18″ 40-hp. gas engine	—	1909

Wolf Lick Run

Plunger pump, 7¼″ × 16″ 150-hp. gas engine	0.870	1907
Air compressor ‡ 30-hp. gas engine	—	1909
Air compressor, 14½″ × 20″ 80-hp. gas engine	—	1920

Luhring Pines

Plunger pump, 8″ × 12″ 100-hp. gas engine Integral air compressor	0.504	1926

† Retired 1901 and replaced by gas power.

‡ Retired 1920. Large compressor salvaged for $450.

Summary of Installations and Retirements
St. Mary's, Pennsylvania

MAINS

1-in. Wrought-Iron Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1900	305	305	0
1941	0	0	0
Total	305	305	0

1¼-in. Wrought-Iron Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1900	1,097	347	750
1913	298	298	0
1941	0	0	0
Total	1,395	645	750

Retirements by Years

Year Installed	*Feet*	*Year*
1900	750	1925

1½-in. Wrought-Iron Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1900	261	261	0
1941	0	0	0
Total	261	261	0

2-in. Wrought-Iron Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1890	300	300	0
1900	5,419	1,425	3,994
1912	350	350	0
1923	173	173	0
1941	0	0	0
Total	6,242	2,248	3,994

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*
1900	3,810	1925	184	1938

4-in. Wrought-Iron Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1889	4,300	0	4,300
1900	2,009	1,690	319
1941	0	0	0
Total	6,309	1,690	4,619

Retirements by Years

Year Installed	*Feet*	*Year*
1889	4,300	1897
1900	319	1939

5-in. Wrought-Iron Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1900	876	876	0
1941	0	0	0
Total	876	876	0

6-IN. WROUGHT-IRON MAINS

Year Installed	Feet Installed	In Service	Retired
1897	4,546	4,390	156
1898	14,862	14,507	355
1900	3,023	3,023	0
1914	101	101	0
1926	82	82	0
1939	355	355	0
1941	0	0	0
TOTAL	22,969	22,458	511

Retirements by Years

Year Installed	Feet	Year
1897	156	1919
1898	355	1939

4-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	In Service	Retired
1891	21,562	21,441	121
1894	1,400	1,400	0
1897	1,682	1,682	0
1898	760	760	0
1900	450	0	450
1902	3,126	3,126	0
1903	475	475	0
1904	2,259	2,259	0
1905	1,536	1,536	0
1906	3,163	3,163	0
1907	520	520	0
1908	1,641	1,641	0
1909	1,596	1,596	0
1910	287	287	0
1911	643	643	0
1912	2,307	2,307	0
1913	1,914	1,914	0
1914	2,074	2,074	0
1915	766	766	0
1917	196	196	0
1919	2,139	2,139	0
1921	1,847	1,847	0
1922	3,041	3,041	0

4-IN. CAST-IRON UNLINED MAINS (contd.)

Year Installed	Feet Installed	In Service	Retired
1923	711	711	0
1924	2,453	2,453	0
1925	1,441	1,441	0
1926	1,785	1,785	0
1927	1,658	1,658	0
1928	1,111	1,111	0
1941	0	0	0
TOTAL	64,543	63,972	571

Retirements by Years

Year Installed	Feet	Year
1891	121	1939
1900	450	1936

6-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	In Service	Retired
1891	5,612	5,612	0
1896	1,440	1,440	0
1897	2,116	2,116	0
1903	2,647	2,647	0
1907	1,423	1,423	0
1913	4,165	4,165	0
1914	8,487	8,487	0
1923	250	250	0
1924	641	641	0
1941	0	0	0
TOTAL	26,781	26,781	0

8-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	In Service	Retired
1907	23,481	23,481	0
1941	0	0	0
TOTAL	23,481	23,481	0

2-IN. CAST-IRON CEMENT-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1931	108	108	0
1936	96	96	0
1937	1,004	1,004	0
1938	1,352	1,352	0
1939	3,807	3,807	0
1940	3,433	3,433	0
1941	0	0	0
TOTAL	9,800	9,800	0

4-IN. CAST-IRON CEMENT-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1931	26	26	0
1934	22	22	0
1935	1,044	1,044	0
1936	96	96	0
1937	60	60	0
1938	174	174	0
1941	0	0	0
TOTAL	1,422	1,422	0

6-IN. CAST-IRON CEMENT-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1928	660	660	0
1929	789	789	0
1930	795	795	0
1931	801	801	0
1933	2,102	2,102	0
1934	801	801	0
1935	1,731	1,731	0
1936	2,686	2,686	0
1939	409	409	0
1941	0	0	0
TOTAL	10,774	10,774	0

8-IN. CAST-IRON CEMENT-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1927	10,107	10,107	0
1941	0	0	0
TOTAL	10,107	10,107	0

METERS

¾-IN. DISC METERS

Year Installed	Number Installed	Number In Service	Number Retired
1918	207	0	207
1919	500	449	51
1920	250	250	0
1921	24	24	0
1922	24	24	0
1923	24	24	0
1924	39	39	0
1925	30	30	0
1926	46	46	0
1927	30	30	0
1928	48	48	0
1929	39	39	0
1930	209	209	0
1931	120	120	0
1933	6	6	0
1934	115	115	0
1935	65	65	0
1936	55	55	0
1937	10	10	0
SUBTOTAL	1,841	1,583	258
Unknown	148	0	148
TOTAL	1,989	1,583	406

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1918	86	1930	121	1931		
1919	23	1931	14	1932	10	1934
	2	1935	2	1936		

¾-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1915	1	0	1
1916	9	0	9
1917	4	0	4
1918	4	0	4
1919	12	12	0
1920	32	32	0
1928	3	3	0
1929	2	2	0
1930	1	1	0
1931	8	8	0
1934	6	6	0
1937	1	1	0
Subtotal	83	65	18
Unknown	29	0	29
Total	112	65	47

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1915	1	1935				
1916	3	1931	3	1932	2	1933
	1	1935				
1917	4	1931				
1918	4	1931				

1-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1914	1	0	1
1919	2	0	2
1920	8	3	5
1924	1	1	0
1926	1	1	0
1928	1	1	0
1929	1	1	0
1930	2	2	0
1931	7	7	0
1932	1	1	0
1933	2	2	0
1936	1	1	0
1937	0	0	0
Total	28	20	8

Retirements by Years

Year Installed	Number	Year	Number	Year
1914	1	1930		
1919	2	1931		
1920	4	1931	1	1933

1¼-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1905	3	2	1
1909	1	1	0
1910	2	2	0
1920	1	1	0
1937	0	0	0
Total	7	6	1

Retirements by Years

Year Installed	Number	Year
1905	1	1936

1½-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1905	1	0	1
1913	2	0	2
1930	1	1	0
1934	3	3	0
1937	0	0	0
Subtotal	7	4	3
Unknown	7	0	7
Total	14	4	10

Retirements by Years

Year Installed	Number	Year	Number	Year
1905	1	1930		
1913	1	1934	1	1935

2-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1920	1	0	1
1923	2	0	2
1925	3	1	2
1933	3	3	0
1937	0	0	0
Subtotal	9	4	5
Unknown	6	0	6
Total	15	4	11

Retirements by Years

Year Installed	Number	Year	Number	Year
1920	1	1931		
1923	1	1931	1	1933
1925	2	1936		

3-IN. DISC METERS

Year Installed	Number Installed	In Service	Retired
1913	2	1	1
1915	1	0	1
1916	1	0	1
1920	1	1	0
1924	1	1	0
1926	1	1	0
1928	3	3	0
1932	1	1	0
1933	1	1	0
1935	1	1	0
1937	0	0	0
SUBTOTAL	13	10	3
Unknown	1	0	1
TOTAL	14	10	4

Retirements by Years

Year Installed	Number	Year
1913	1	1932
1915	1	1932
1916	1	1932

4-IN. CURRENT METERS

Year Installed	Number Installed	In Service	Retired
1914	1	0	1
1928	1	1	0
1937	0	0	0
TOTAL	2	1	1

Retirements by Years

Year Installed	Number	Year
1914	1	1937

6-IN. CURRENT METERS

Year Installed	Number Installed	In Service	Retired
1914	1	1	0
1937	0	0	0
TOTAL	1	1	0

HYDRANTS

4-IN. HYDRANTS

Year Installed	Number Installed	In Service	Retired
1889	40	27	13
1901	6	1	5
1903	3	3	0
1904	1	1	0
1905	1	1	0
1906	1	1	0
1907	1	1	0
1909	2	2	0
1910	2	2	0
1912	2	2	0
1913	2	2	0
1915	3	3	0
1920	1	1	0
1921	4	4	0
1922	3	3	0
1926	3	3	0
1928	2	2	0
1929	5	5	0
1930	1	1	0
1931	1	1	0
1933	1	1	0
1934	2	2	0
1935	2	2	0
1936	2	2	0
1937	0	0	0
TOTAL	91	73	18

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1889	2	1920	3	1928	8	1935
1901	2	1935	3	1937		

Denver, Colorado—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1940

THE Denver Municipal Water Works, owned and operated by the municipality, serves the city of Denver and several outside districts, including Englewood, Fort Logan, Edgewater, Aurora and Fitzsimons Hospital.

Besides being the state capital, Denver is regional headquarters for numerous federal activities, and is an important commercial, distributing and financial center for the Rocky Mountain States. Industrial activity is not prominent.

As of the date of the study there were 77,122 consumers receiving service, of which only 2,568 were metered. Water delivered to the system averaged 64 mgd., serving approximately 360,000 people, or about 178 gpd. per capita.

Development of the Existing System

The oldest works of the present system were built in 1870, when the population was 4,759. Delivery of water began in 1872 from a station pumping from a well near the Platte River. The early history of water supply included considerable competition between several supply and distributing companies. The Denver City Water Co. (1870) and the Denver City Irrigation and Water Co. (1878) combined to form the Denver Water Co. (1882) and in 1890 this company took over the Domestic Water Co., which had been formed in 1886. In the meantime two other companies, the Beaver Brook Water Co. (1886) and the Mountain Water Co. (1888), were formed and consolidated with the Denver Water Co. to form the Denver City Water Works Co. (1890), which was purchased by the American Water Works Co. of New Jersey in 1891.

In 1889 an independent local company, the Citizens Water Co., was formed. It continued in competition with the American Water Works Co. until 1894, when the two companies consolidated to form the Denver Union Water Co. The South Platte Canal and Reservoir Co. was organized in 1894 to build the Cheesman Dam, which was, upon completion, leased to the Denver Union Water Co.

In 1918 the existing water works systems were purchased by the city and since then have been owned and operated by the city through a board of water commissioners.

The early history of the formation of the existing system is important in this study, since it produced several competing systems within the same service areas having duplicating pipelines and other facilities. In 1896, the first steps were taken to eliminate duplicate pipes and between that date and 1914 a considerable portion of the duplicate distribution mains were either taken up or abandoned.

The sources of the supply for Denver have been developed over the years, with the South Platte River system located south of the city and the Fraser

River system, west of the Continental Divide, forming two independent major sources.

The South Platte system secures its supply largely from the South Platte River at Intake. Subsidiary sources are located on the tributaries, Bear and Cherry Creeks. Antero (1910), Platte Cañon (1904) and Eleven Mile Cañon (1932) reservoirs, Lake Cheesman (1904) and Marston Lake (1898) provide storage on this watershed. Lake

TABLE 1

SUMMARY OF MAINS

DENVER, COLORADO

Size, in.	Kind	No. of Feet Installed	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percentage of Total	Year of First Installation	Average Age, yr.
48	Cast-iron	250	0.0	0	0.0	250	0.0	1925	12.8
46	Concrete	6,968	0.1	0	0.0	6,968	0.1	1940	0.5
42	Cast-iron	143	0.0	0	0.0	143	0.0	1924	15.0
42	Concrete	3,169	0.1	0	0.0	3,169	0.1	1940	0.5
41.34	Cast-iron	2,483	0.0	0	0.0	2,483	0.0	1924	16.5
39.37	Cast-iron	2,286	0.0	0	0.0	2,286	0.0	1924	16.5
36	Cast-iron	14,601	0.3	0	0.0	14,601	0.3	1924	15.4
30	Cast-iron	54,494	1.1	434	0.0	54,060	1.3	1888	20.1
30	Wood-stave	2,513	0.1	2,513	0.3	0	0.0	1888	—
30	Concrete	16,862	0.3	0	0.0	16,862	0.4	1938	2.3
30	Steel	2,533	0.1	0	0.0	2,533	0.1	1928	12.5
24	Cast-iron	121,032	2.3	4,523	0.5	116,509	2.8	1890	30.2
24	Wood-stave	6,552	0.1	6,552	0.7	0	0.0	1889	—
24	Steel	2,763	0.1	0	0.0	2,763	0.1	1911	27.8
20	Cast-iron	47,381	0.9	12,137	1.2	35,244	0.8	1880	24.4
18	Cast-iron	26,511	0.5	354	0.0	26,157	0.6	1888	39.1
16	Cast-iron	111,498	2.2	9,797	1.0	101,701	2.5	1888	34.5
15	Cast-iron	6,177	0.1	0	0.0	6,177	0.1	1872	68.5
14	Cast-iron	34,840	0.7	892	0.1	33,948	0.8	1888	50.0
12	Cast-iron	695,650	13.5	61,203	6.0	634,447	15.3	1881	28.0
10	Cast-iron	109,953	2.1	18,267	1.8	91,686	2.2	1881	46.5
8	Cast-iron	394,076	7.6	27,339	2.7	366,737	8.8	1881	28.5
6	Cast-iron	1,915,355	37.1	276,424	27.2	1,638,931	39.5	1878	36.4
4	Cast-iron	619,711	12.0	248,064	24.4	371,647	9.0	1878	49.7
3	Cast-iron, Galvanized-iron	389,159	7.5	79,363	7.8	309,796	7.5	1881	11.0
2½	Galvanized-iron	1,090	0.0	275	0.0	815	0.0	1907	33.5
2	Galvanized-iron	526,585	10.2	239,524	23.6	287,061	6.9	1884	20.6
1½	Galvanized-iron	24,046	0.5	15,072	1.5	8,974	0.2	1890	31.3
1¼	Galvanized-iron	13,864	0.3	8,406	0.8	5,458	0.1	1890	32.7
1	Galvanized-iron	10,012	0.2	3,997	0.4	6,015	0.1	1895	31.7
TOTAL		5,162,557	100.0	1,015,136	100.0	4,147,421	100.0		32.1
Percentage of Total		100.0		19.7		80.3			
Average Size, in.		7.60		5.23		8.18			

TABLE 1 (contd.)

Mortality Survival Ratios

Size, in.	Kind	No. of Feet	Period Covered, yr.	Percentage
1–1½	Galvanized-iron	47,922	45.5	32.894
2–3	Cast-iron, Galvanized-iron	916,834	58.5	0.000
4	Cast-iron	619,711	62.5	59.142
6	Cast-iron	1,915,355	62.5	82.943
8	Cast-iron	394,076	59.5	88.908
10 and 12	Cast-iron	805,603	59.5	87.455
Over 12	Cast-iron	421,696	68.5	86.507
SUBTOTAL		5,121,197		
Other Kinds		41,360		
TOTAL		5,162,557		

TABLE 2

SUMMARY OF CONDUITS
DENVER, COLORADO

Size, in.	Kind	No. of Feet Installed	No. of Feet Retired	No. of Feet in Service	Year of First Installation	Average Age, yr.
84	Concrete	619	0	619	1925	15.5
72	Concrete Tunnel	66	0	66	1911	29.5
66	Concrete	31,471	0	31,471	1925	15.5
66	Steel	4,873	0	4,873	1925	12.6
66	Wood-stave	65,024	12,597	52,427	1925	12.8
63	Steel	17,563	0	17,563	1938	2.5
60	Cast-iron	67	0	67	1911	29.5
60	Concrete	57,722	0	57,722	1930	10.5
60	Steel	1,179	0	1,179	1911	28.7
60	Wood-stave	13,083	714	12,369	1911	28.5
57	Steel	12,581	0	12,581	1938	2.5
54	Concrete	69,915	662	69,253	1921	13.4
54	Steel	8,936	0	8,936	1925	15.5
51	Steel	6,344	0	6,344	1938	2.5
48	Cast-iron	2,222	1,743	479	1910	24.6
48	Steel	8,784	3,345	5,439	1910	15.5
48	Wood-stave	152,207	99,676	52,531	1884	28.6
44	Wood-stave	8,517	7,346	1,171	1893	47.5
42	Cast-iron	541	0	541	1899	36.6
42	Concrete	20,550	0	20,550	1938	2.5
42	Steel	45,613	0	45,613	1938	2.5
40	Wood-stave	114,256	110,819	3,437	1884	9.5
38	Concrete Tunnel	12,336	7,722	4,614	1893	47.5
36	Cast-iron	36,228	1,496	34,732	1884	18.0
36	Concrete	2,892	0	2,892	1907	29.0
36	Steel	244	0	244	1938	2.5
36	Wood-stave	11,250	7,306	3,944	1899	29.8

TABLE 2 (contd.)

Size, *in.*	Kind	No. of Feet Installed	No. of Feet Retired	No. of Feet in Service	Year of First Installation	Average Age, *yr.*
34	Steel	4,162	0	4,162	1893	23.1
34	Wood-stave	96,076	51,534	44,542	1893	43.3
30	Cast-iron	22,530	1,134	21,396	1890	46.8
30	Concrete	26,303	0	26,303	1939	1.5
30	Steel	3,567	2,936	631	1929	2.5
30	Wood-stave	161,465	134,517	26,948	1890	29.2
16	Cast-iron	1,941	0	1,941	1939	1.5
16	Steel	300	0	300	1933	7.5
TOTAL		1,021,427	443,547	577,880		16.9
Percentage of Total		100.0	43.4	56.6		
Average Size, *in.*		43.8	38.5	49.6		

Mortality Survival Ratios *

Size, *in.*	Kind	No. of Feet	Period Covered, *yr.*	Percentage
16–60	Cast-iron	63,529	51.5	84.414
30–84	Concrete	236,471	33.5	99.205
16–66	Steel	119,442	47.5	37.459
24–66	Wood-stave	630,948	56.5	9.526
TOTAL		1,050,390		

* Including distribution mains other than cast-iron. Concrete-lined tunnel not included.

Cheesman and Eleven Mile Cañon reservoirs each impound about 26 bil. gal.

The intake (1912) on the South Platte receives the flow from Lake Cheesman and Eleven Mile Cañon Reservoir and diverts it through a conduit to the Platte Cañon Reservoir and Marston Lake. Harriman and Soda lakes, supplied from Bear Creek, are auxiliary to Marston Lake. The supply from Cherry Creek (1888) is independently secured from an infiltration gallery and is serviced directly to the city.

The supply from the South Platte system is purified at Waterton by the Kassler slow sand filters, of 30-mgd. capacity (1903), located near Platte Cañon Reservoir and in the South Side Marston filter plant (1894), capacity 21 mgd,, and the North Side plant (1925), capacity 64 mgd., both rapid sand filtration plants.

The Transmountain Water Diversion, or Fraser River system, first projected in 1914, was initially placed in service, through the completion of the Moffat Tunnel, in 1938. The diversion of the Vasquez, Buck and Jim creeks and the Fraser River provides the supply through the Moffat Tunnel, which is 6.3 mi. in length with an inside diameter of 10.5 ft. From the Moffat Tunnel the water flows down South Boulder Creek to an intake where it is

TABLE 3

SUMMARY OF VALVES
DENVER, COLORADO

Size, in.	Number Installed	Number Retired	Number in Service	Year of First Installation	Average Age, yr.
48	4	0	4	1925	11.5
42	4	1	3	1924	5.8
36	22	0	22	1924	13.4
30	45	1	44	1888	16.9
24	150	7	143	1890	24.3
20	48	5	43	1881	24.5
18	42	1	41	1890	37.8
16	150	10	140	1890	33.0
15	8	0	8	1872	57.3
14	74	9	65	1890	45.9
12	1,820	86	1,734	1883	24.6
10	263	24	239	1890	39.0
8	1,311	47	1,264	1883	23.7
6	5,475	379	5,096	1880	33.1
4	943	277	666	1881	37.5
3	783	161	622	1881	10.4
2½	3	1	2	1907	17.5
2	1,129	518	611	1890	17.9
1½	60	23	37	1892	24.6
1¼	34	16	18	1890	24.3
1	30	11	19	1895	29.1
TOTAL	12,398	1,577	10,821		28.7
Percentage of of Total	100.0	12.7	87.3		

Mortality Survival Ratios

Size, in.	Number	Period Covered, yr.	Percentage
1–1½	124	45.5	42.245
2–3	1,915	58.5	0
4	943	52.5	60.102
6	5,475	60.5	83.265
8	1,311	57.5	89.290
10 and 12	2,083	57.5	91.227
Over 12	547	68.5	68.298
TOTAL	12,398		

diverted to Ralston Creek Reservoir and thence through a conduit to the Moffat filter plant, a recently built rapid sand plant of 56-mgd. capacity.

A system of conduits from the filter plants carries the filtered water to the city, where there are located three distribution reservoirs, the 35-mil.gal.

TABLE 4

SUMMARY OF HYDRANTS, HYDRANT VALVES AND LATERALS
DENVER, COLORADO

Size, *in.*	Number Identified	Number Retired	Number in Service	Year of First Installation	Average Age, *yr.*	Mortality Survival Ratio, %
Hydrants, each						
4	612	243	369	1885	41.5	51.622
6	4,298	132	4,166	1889	34.9	94.676
TOTAL	4,910	375	4,535		35.4	
Percentage of Total	100.0	7.64	92.36			
Hydrant Laterals, ft. pipe						
4 (Cast-iron)	6,633	2,185	4,448	1889	43.8	61.117
6 (Cast-iron)	53,300	2,369	50,931	1889	35.4	93.114
TOTAL	59,933	4,554	55,379		36.0	
Percentage of Total	100.0	7.60	92.40			
Hydrant Valves, each						
4	498	177	321	1889	36.6	49.256
6	4,487	194	4,293		32.6	91.847
TOTAL	4,985	371	4,614		32.9	
Percentage of Total	100.0	7.44	92.56			

TABLE 5

SUMMARY OF LEAD SERVICES
DENVER, COLORADO

Size, *in.*	Number Installed	Number Retired	Number in Service	Year of First Installation	Average Age, *yr.*
½	5,121	921	4,200	1875	49.7
⅝	33,661	1,739	31,922	1875	36.7
¾	33,821	1,027	32,794	1875	19.1
1	2,164	135	2,029	1875	32.0
1¼	312	12	300	1887	22.5
1½	480	28	452	1888	35.7
2	144	10	134	1881	34.7
3	26	4	22	1900	16.0
TOTAL	75,729	3,876	71,853		29.2
Percentage of Total	100.0	5.1	94.9		

TABLE 5 (contd.)

Mortality Survival Ratios

Size, in.	Number	Period Covered, yr.	Percentage
½	5,121	65.5	81.284
⅝	33,661	65.5	89.314
¾	33,821	65.5	82.250
1–3	3,126	65.5	88.600
TOTAL	75,729		

Capital Hill Reservoir (1888 and 1907), the 41-mil.gal. Ashland Avenue Reservoir (1891) and the 5-mil.gal. Montclair Reservoir. Pumping stations with electrical equipment at each of these points serve the higher districts, while the business section and the lower portions along the Platte River receive their supply by gravity from the South Platte system.

The transmission or conduit system consists of approximately 115 mi. of cast-iron, wood stave, steel and concrete pipe from 16 to 84 in. in diameter. In the distribution system there are approximately 13 mi. of 1- to 48-in. diameter pipe outside the city and 777 mi. within the city. Except for the smaller galvanized-iron mains, the pipe system consists almost entirely of Class B tar-coated cast-iron pipe laid with a cover of 4½ ft. There are over 15,400 valves and 4,500 hydrants in the system. The 77,000 services are almost entirely of lead.

Basis of Study

The records of the system pertaining to distribution and transmission mains, valves, hydrants and services are substantially complete from the original date of construction or installation. The early wood distribution mains are not included in this study. Record drawings of the pipe system, with card index records of valves and hydrants, are available. The city has a complete record of service installations and retirements. No attempt was made to compile the record of Class B facilities, or of the few meters in the system.

Mortality Survival Study

Mortality survival studies of the transmission and distribution pipe, valves, hydrants and hydrant laterals and services were made. Table 1 is a summary of all the distribution pipe installed and retired and data relating to the average ages of the surviving pipe, length of record, average sizes and mortality survival ratios. Table 2 is a similar table pertaining to the conduits. Figures 1, 2 and 3 show the mortality survival curves for the facilities covered by the respective tables.

While generally in these studies the mortality survival curves have been based upon the mortality effects of the entire retirement history of the facilities studied, in the case of Denver there have been drawn on Fig. 1 the mortality survival curves for 4- and 6-in. pipe, based on the retirements which have taken place in the 20-year period from 1920 to 1940. The reason for the very great difference in the respec-

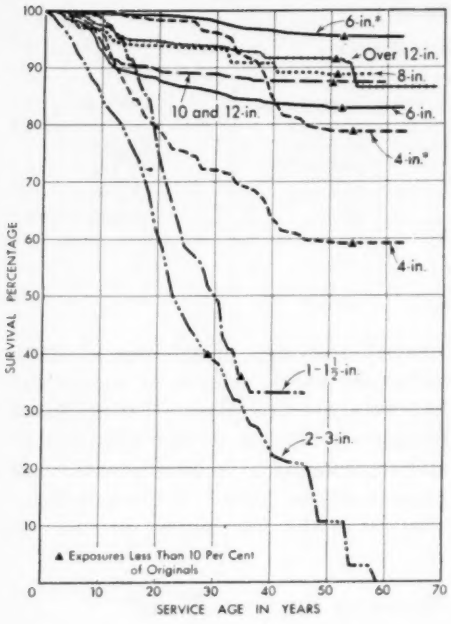


FIG. 1. Mortality Survival Curve—1–48-in. Mains—Denver, Colorado

BASE: Feet SURVIVAL: 1872–1940, 1920–1940

SIZE in.	KIND	EXPOSURES ft.	RETIREMENTS ft.
1–1½	Galvanized-Iron	47,922	27,475
2–3	Galvanized-Iron	916,834	319,162
4*	Cast-Iron Unlined	466,174	94,527
4	Cast-Iron Unlined	619,711	248,064
6*	Cast-Iron Unlined	1,690,190	51,259
6	Cast-Iron Unlined	1,915,355	276,424
8	Cast-Iron Unlined	394,076	27,339
10 and 12	Cast-Iron Unlined	805,603	79,470
Over 12	Cast-Iron Unlined	421,696	28,137

* Retired 1920–1940.

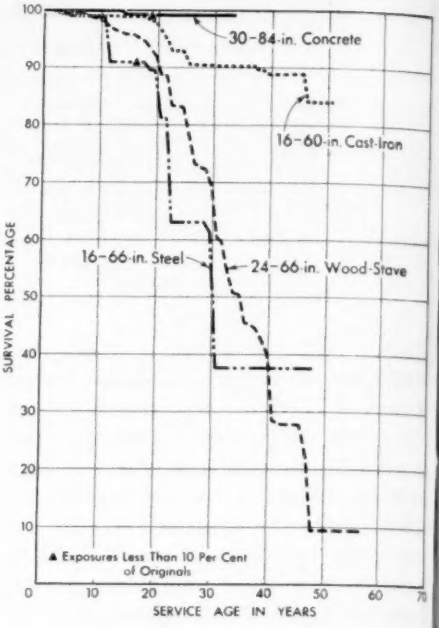


FIG. 2. Mortality Survival Curve—16–84-in. Transmission Mains—Denver, Colorado

BASE: Feet SURVIVAL: 1884–1940

SIZE in.	KIND	EXPOSURES ft.	RETIREMENTS ft.
16–60	Cast-Iron	63,529	4,373
24–66	Wood-Stave	630,948	433,574
30–84	Concrete	236,471	662
16–66	Steel	119,442	6,281

tive curves is due almost entirely to the retirement, either by the removal or the abandonment of the pipe, of some of the duplicate mains arising from the competing systems serving the territory in its early history.

Table 3 is a summary of the distribution valves and appurtenant data and Fig. 3 shows the corresponding mortality survival curves.

Table 4 and Fig. 4 give the similar data applicable to hydrants and hydrant laterals and valves.

Table 5 and Fig. 5 show similar studies of the lead services.

The basic data covering the installations and retirements are appended hereto.

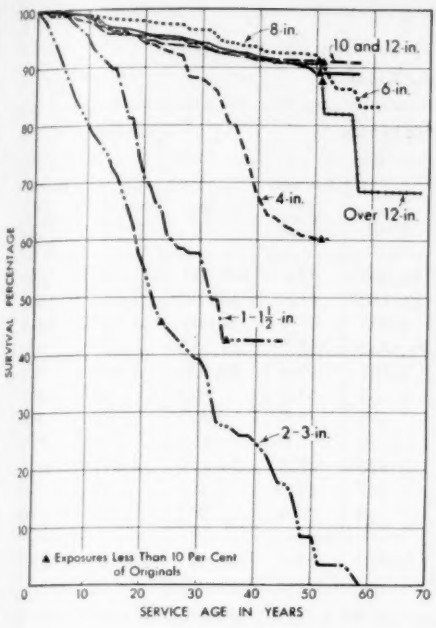


FIG. 3. Mortality Survival Curve—1–48-in. Gate Valves—Denver, Colorado

BASE: Unit SURVIVAL: 1872–1940

SIZE *in.*	EXPOSURES *Units*	RETIREMENTS *Units*
1–1½	124	50
2–3	1,915	680
4	943	277
6	5,475	379
8	1,311	47
10 and 12	2,083	110
Over 12	547	34

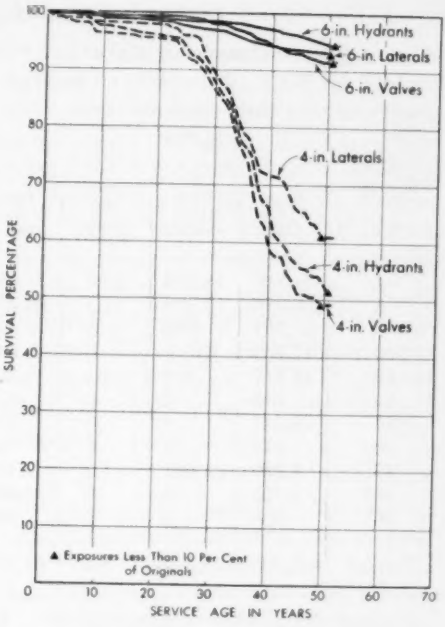


FIG. 4. Mortality Survival Curve—4–6-in. Hydrants and Appurtenances—Denver, Colorado

BASE: Unit SURVIVAL: 1889–1940

	SIZE *in.*	EXPOSURES *Units*	RETIREMENTS *Units*
Valves	4	498	177
	6	4,487	194
Laterals	4	6,633	2,185
	6	53,300	2,369
Hydrants	4	612	243
	6	4,298	132

Causes of Retirements

The records of the department indicate substantially the number of cast-iron pipe units which have been taken out and those which have been abandoned since the inception of the system. A similar division of retirements is available for gate valves. Table 6 shows the footage of cast-iron pipe identifiable as to whether it was taken out or abandoned, divided into two periods, from the beginning to 1914 and from 1914 to 1940. The first period covers the time when duplicating mains were actively being eliminated. It is estimated by department officials that, in their tenure of office,

TABLE 6

SUMMARY OF CAST-IRON PIPE TAKEN OUT OR ABANDONED
DENVER, COLORADO

Size, *in.*	To 1914			1914 to 1940			Total Period		
	Feet Taken Out	Feet Abandoned	Percentage Abandoned	Feet Taken Out	Feet Abandoned	Percentage Abandoned	Feet Taken Out	Feet Abandoned	Percentage Abandoned
4	94,880	13,638	12.6	12,657	94,007	88.1	107,537	107,645	50.0
6	210,036	3,209	1.5	36,430*	25,460	41.1	246,466*	28,669	10.4
8	27,707	496	1.8	6,390	3,897	37.9	34,097	4,393	11.4
10	17,200	0	0	333	732	68.7	17,533	732	4.0
12	41,817	519	1.2	7,389	1,391	15.8	49,206	1,910	3.7
14	678	0	0	125	62	33.2	803	62	7.2
16	8,555	0	0	438	472	51.9	8,993	438	4.6
18	140	0	0	24	0	0	164	0	0
20	7,960	1,001	11.2	2,459	570	18.8	10,419	1,571	13.1
24	3,252	0	0	1,065	227	17.6	4,317	227	5.0
30	168	0	0	640	0	0	808	0	0
TOTAL	412,393	18,863	4.4	67,950	126,818	65.1	480,343	145,647	23.3

* Includes 1,287 ft. of 6-in. pipe sold. Estimated 80 per cent of cast-iron pipe taken out is salvaged and relaid.

Retirement of Pipe Due to Parallel Mains Following Consolidation of Companies

Company	No. of Feet in 1894	Feet Taken Out	Feet Abandoned	Feet Retired	Feet Remaining in 1914
American Water Works Co.					
Conduits	55,097	0	0	0	55,097
Distribution mains	1,241,772	283,958	0	283,958	957,814
Beaver Brook and Mountain Water Co.					
Distribution mains	215,619	0	0	0	215,619
Citizens Water Co.					
Conduits	236,861	5,032	5,343	10,375	226,486
Distribution mains	515,914	183,264	354	183,618	332,296
TOTAL	2,265,263	472,254	5,697	477,951	1,787,312

approximately 80 per cent of all cast-iron pipe taken out has been salvaged and reinstalled in other locations. There is included in this table an analysis of the retirements of parallel mains brought about by the consolidation of competing water distribution companies.

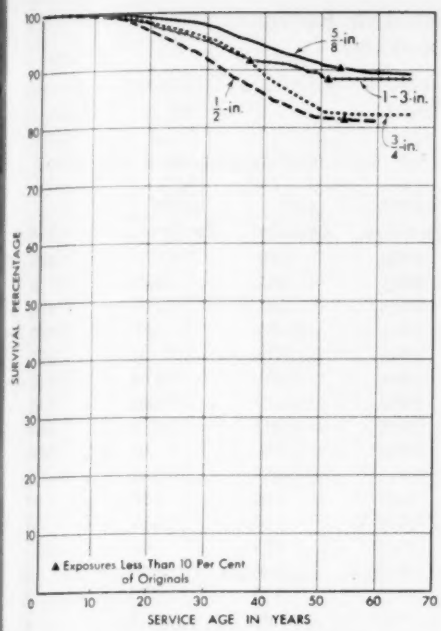


FIG. 5. Mortality Survival Curve—½–3-in. Lead Services—Denver, Colorado

BASE: Unit SURVIVAL: 1875–1940

SIZE *in.*	EXPOSURES *Units*	RETIREMENTS *Units*
½	5,121	921
⅝	33,661	1,739
¾	33,821	1,027
1–3	3,126	189

Table 7 gives the proportions of gate valves identified as abandoned or taken out in the period from 1914 to 1940.

Acknowledgments

The collection and compilation of data pertaining to the study in Denver were made possible through the efforts of George F. Hughes, Executive Secretary and a member of the Committee on Survival and Retirement Experience With Water Works Facilities. The work of abstracting the records of installation and retirement of the facilities studied was carried out by the regular staff of the department, under the general direction of D. D. Gross, Chief Engineer, and John Burgess, Engineer.

TABLE 7

SUMMARY OF IDENTIFIED VALVES TAKEN OUT OR ABANDONED, 1914 TO 1940 DENVER, COLORADO

Size, *in.*	Number Taken Out	Number Abandoned	Percentage Abandoned
4	101	126	55.5
6	174*	47	21.3
8	28	5	15.2
10	14	0	0
12	27	0	0
14	3	0	0
18	1	0	0
20	3	1	25.0
24	5	0	0
30	1	0	0
42	1	0	0
TOTAL	358	179	33.3

* Includes one 6-in. valve sold.

Summary of Installations and Retirements
Denver, Colorado

Mains

1-in. Galvanized-Iron Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1895	655	466	189
1901	817	92	725
1902	600	600	0
1904	1,473	242	1,231
1905	325	0	325
1906	288	288	0
1907	1,097	650	447
1908	1,014	1,014	0
1909	697	328	369
1910	892	806	86
1911	709	405	304
1912	225	225	0
1913	140	0	140
1914	144	144	0
1917	469	288	181
1923	35	35	0
1924	48	48	0
1929	124	124	0
1931	250	250	0
1938	3	3	0
1939	7	7	0
1940	0	0	0
Total	10,012	6,015	3,997

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1895	189	1926				
1901	425	1926	300	1927		
1904	500	1925	30	1926	58	1927
	300	1931	343	1938		
1905	325	1939				
1907	227	1924	140	1931	80	1935
1909	168	1925	201	1935		
1910	86	1929				
1911	304	1928				
1913	140	1923				
1917	181	1927				

1¼-in. Galvanized-Iron Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1890	680	0	680
1898	465	465	0
1903	1,385	1,015	370
1904	2,967	387	2,580
1905	595	0	595
1906	1,801	274	1,527
1907	1,419	886	533
1908	1,602	1,038	564
1909	566	0	566
1911	361	361	0
1914	136	136	0
1915	110	110	0
1917	413	96	317
1918	440	440	0
1919	173	173	0
1923	81	7	74
1926	606	6	600
1927	5	5	0
1933	39	39	0
1936	20	20	0
1940	0	0	0
Total	13,864	5,458	8,406

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1890	680	1922				
1903	370	1931				
1904	1,850	1923	730	1926		
1905	350	1923	245	1928		
1906	155	1925	330	1926	372	1928
	400	1930	270	1936		
1907	203	1923	330	1931		
1908	564	1936				
1909	229	1925	144	1930	193	1940
1917	29	1924	288	1931		
1923	74	1930				
1926	600	1938				

1½-IN. GALVANIZED-IRON MAINS

Year Installed	Feet			Year Installed	Feet		
	Installed	In Service	Retired		Installed	In Service	Retired
1890	355	0	355	1914	301	0	301
1892	1,559	0	1,559	1915	397	0	397
1896	567	0	567	1916	325	0	325
1898	931	0	931	1917	121	0	121
1902	454	454	0	1918	182	0	182
1903	211	168	43	1924	124	3	121
1904	2,068	0	2,068	1925	193	193	0
1905	1,322	537	785	1927	36	11	25
1906	775	0	775	1929	12	12	0
1907	2,341	1,469	872	1930	30	30	0
1908	3,286	1,434	1,852	1932	43	43	0
1909	2,030	1,190	840	1934	15	15	0
1910	2,971	1,450	1,521	1936	16	16	0
1911	666	666	0	1940	5	5	0
1912	2,588	1,156	1,432				
1913	122	122	0	TOTAL	24,046	8,974	15,072

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year	Year Installed	Feet	Year	Feet	Year	Feet	Year
1890	355	1926					1909	140	1926	46	1928	654	1929
1892	1,559	1923					1910	737	1926	784	1930		
1896	567	1925					1912	1,311	1926	121	1928		
1898	931	1926					1914	256	1928	45	1931		
1903	43	1932					1915	397	1927				
1904	768	1923	1230	1927	70	1931	1916	325	1926				
1905	200	1924	585	1929			1917	121	1928				
1906	475	1926	300	1930			1918	182	1927				
1907	150	1925	699	1928	23	1939	1924	121	1935				
1908	277	1924	359	1925	280	1928	1927	25	1935				
	500	1930	350	1938	86	1940							

2-IN. GALVANIZED-IRON MAINS

Year Installed	Feet			Year Installed	Feet		
	Installed	In Service	Retired		Installed	In Service	Retired
1884	335	0	335	1901	495	0	495
1890	1,230	1,230	0	1902	2,310	0	2,310
1891	85	85	0	1903	2,629	1,418	1,211
1892	2,263	340	1,923	1904	10,824	3,325	7,499
1893	1,643	0	1,643	1905	11,390	4,532	6,858
1894	853	0	853	1906	12,209	3,824	8,385
1896	819	0	819	1907	5,933	1,094	4,839
1897	4,271	0	4,271	1908	20,998	10,604	10,394
1898	781	25	756	1909	31,342	14,271	17,071
1899	846	0	846	1910	20,648	6,733	13,915

2-IN. GALVANIZED-IRON MAINS (contd.)

Year Installed	Feet		
	Installed	In Service	Retired
1911	33,798	15,792	18,006
1912	13,694	5,132	8,562
1913	7,277	604	6,673
1914	1,522	0	1,522
1915	2,084	0	2,084
1916	909	0	909
1917	7,185	2,295	4,890
1918	1,291	891	400
1919	5,130	2,641	2,489
1920	23,011	12,909	10,102
1921	46,492	25,669	20,823
1922	80,980	49,419	31,561
1923	55,770	32,479	23,291
1924	33,495	23,056	10,439
1925	37,417	30,455	6,962
1926	23,801	19,947	3,854
1927	5,642	4,996	646
1928	3,092	2,353	739
1929	3,180	2,363	817
1930	796	712	84
1931	546	531	15
1932	1,980	1,929	51
1933	681	681	0
1934	369	369	0
1935	913	878	35
1936	674	674	0
1937	1,313	1,313	0
1938	788	692	96
1939	404	353	51
1940	447	447	0
TOTAL	526,585	287,061	239,524

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1884	335	1899				
1892	721	1923	873	1924	287	1928
	42	1933				
1893	539	1935	565	1936	539	1937
1894	650	1923	203	1931		
1896	407	1927	412	1929		
1897	548	1913	2,140	1923	1,246	1924
	337	1939				
1898	600	1911	156	1938		
1899	846	1928				
1901	240	1924	255	1927		
1902	1,704	1913	209	1924	397	1930
1903	1,211	1924				
1904	2,626	1923	460	1924	220	1925
	1,063	1927	1,762	1931	670	1933
	199	1937	499	1940		
1905	2,892	1924	1,271	1925	887	1928
	590	1929	270	1930	175	1932
	457	1933	316	1940		
1906	587	1923	4,245	1924	26	1925
	28	1927	575	1928	647	1929
	1,064	1930	152	1931	81	1933
	185	1937	465	1938	330	1939
1907	650	1922	612	1923	41	1925
	271	1928	22	1929	941	1931
	1,552	1932	600	1938	150	1939
1908	925	1924	625	1927	625	1928
	845	1929	2,653	1930	2,259	1931
	654	1936	1,808	1940		
1909	704	1923	2,594	1924	1,139	1925
	889	1926	707	1927	3,909	1928
	1,205	1929	1,662	1930	2,783	1931
	617	1933	862	1939		
1910	2,139	1923	4,248	1924	1,573	1925
	117	1926	1,104	1927	971	1928
	1,472	1929	443	1930	359	1931
	277	1932	344	1933	585	1935
	283	1939				
1911	575	1923	2,255	1924	364	1925
	1,843	1926	3,425	1927	3,023	1928
	948	1930	2,625	1931	31	1932
	253	1933	590	1935	732	1938
	537	1939	805	1940		
1912	1,105	1923	1,861	1924	911	1926
	882	1927	1,048	1930	1,527	1931
	140	1932	696	1935	392	1937
1913	229	1923	3,011	1924	187	1927
	530	1928	1,472	1930	1,244	1931
1914	244	1920	409	1931	603	1936
	266	1940				
1915	935	1926	278	1930	871	1940
1916	335	1926	287	1927	287	1931
1917	2,125	1924	698	1928	2,067	1931
1918	400	1931				
1919	360	1924	23	1925	360	1926
	1,278	1928	412	1931	56	1934
1920	1,093	1925	335	1926	925	1927
	1,936	1928	2,710	1929	407	1930
	968	1931	720	1932	694	1937
	314	1940				
1921	410	1923	1,406	1925	967	1926
	1,926	1927	3,562	1928	1,527	1929
	668	1930	5,736	1931	83	1932
	83	1933	2,302	1939	2,153	1940
1922	1,194	1923	982	1924	2,936	1925
	1,170	1926	5,444	1927	2,473	1928

2-IN. GALVANIZED-IRON MAINS (contd.)

Retirements by Years (contd.)

Year Installed	Feet	Year	Feet	Year	Feet	Year	Year Installed	Feet	Year	Feet	Year	Feet	Year
	1,397	1929	2,519	1930	6,590	1931	1926	448	1929	249	1930	1,070	1931
	1,987	1932	377	1935	328	1937		54	1932	129	1933	90	1936
	178	1938	3,772	1939	214	1940		143	1937	1,671	1940		
1923	561	1923	1,912	1925	1,812	1927	1927	26	1928	54	1930	334	1931
	5,789	1928	733	1929	1,334	1930		97	1932	135	1940		
	3,830	1931	627	1932	630	1933	1928	79	1929	452	1931	106	1932
	78	1937	2,332	1939	3,763	1940		102	1938				
1924	351	1926	1,077	1927	1,099	1928	1929	68	1930	749	1939		
	1,495	1929	225	1930	3,344	1931	1930	84	1940				
	713	1932	60	1933	209	1937	1931	15	1937				
	682	1938	707	1939	477	1940	1932	51	1938				
1925	182	1925	133	1926	682	1927	1935	35	1937				
	349	1928	1,412	1929	119	1930	1938	96	1939				
	1,514	1931	500	1932	542	1933	1939	51	1939				
	27	1934	543	1937	606	1938							
	90	1939	263	1940									

2½-IN. GALVANIZED-IRON MAINS

Year Installed	Feet			Retirements by Years		
	Installed	In Service	Retired	Year Installed	Feet	Year
1907	815	815	0	1911	275	1924
1911	275	0	275			
1940	0	0	0			
TOTAL	1,090	815	275			

3-IN. CAST-IRON AND GALVANIZED-IRON MAINS

Year Installed	Feet			Year Installed	Feet		
	Installed	In Service	Retired		Installed	In Service	Retired
1881	23,119	0	23,119	1927	26,941	23,595	3,346
1883	2,470	0	2,470	1928	40,920	36,439	4,481
1888	49	0	49	1929	19,789	17,254	2,535
1890	110	0	110	1930	16,474	14,021	2,453
1891	679	0	679	1931	9,161	7,740	1,421
1892	4,219	0	4,219	1932	10,030	9,544	486
1897	410	0	410	1933	5,965	5,840	125
1912	660	660	0	1934	4,026	3,899	127
1917	440	404	36	1935	11,216	10,188	1,028
1920	1,135	0	1,135	1936	14,040	11,507	2,533
1921	2,646	2,612	34	1937	16,988	16,841	147
1922	10,834	8,256	2,578	1938	12,423	11,946	477
1923	28,616	20,651	7,965	1939	13,808	13,723	85
1924	42,735	35,884	6,851	1940	15,021	14,918	103
1925	35,196	28,492	6,704				
1926	19,039	15,382	3,657	TOTAL	389,159	309,796	79,363

3-IN. CAST-IRON AND GALVANIZED-IRON MAINS (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1881	2,642	1891	1,480	1893	835	1895
	480	1896	655	1899	1,220	1901
	5,470	1902	680	1903	1,017	1905
	500	1906	500	1912	257	1913
	1,683	1916	482	1927	1,350	1928
	1,968	1929	1,375	1934	57	1938
	468	1939				
1883	450	1895	1,120	1902	900	1906
1888	49	1890				
1890	100	1902	10	1916		
1891	679	1924				
1892	2,600	1904	1,297	1906	322	1924
1897	410	1924				
1917	36	1931				
1920	1,135	1925				
1921	34	1930				
1922	20	1925	663	1927	371	1928
	130	1929	1,394	1932		
1923	2,120	1925	230	1926	1,255	1927
	1,858	1928	937	1931	1,525	1932
1924	26	1939	14	1940		
	943	1925	226	1926	831	1928
	204	1930	2,141	1931	877	1932
	80	1933	1,549	1938		
1925	30	1925	135	1926	2,521	1927
	27	1928	9	1929	839	1931
	162	1933	700	1937	187	1939

Year Installed	Number	Year	Number	Year	Number	Year
1925	2,094	1940				
1926	177	1927	82	1928	263	1930
	995	1931	1,645	1932	171	1937
	10	1939	314	1940		
1927	117	1927	183	1928	767	1930
	1,636	1931	223	1932	76	1934
	168	1936	176	1937		
1928	67	1929	557	1930	1,084	1931
	1,283	1932	403	1935	233	1937
	587	1938	202	1939	65	1940
1929	253	1930	122	1931	303	1932
	602	1937	1,255	1940		
1930	17	1930	1,327	1932	125	1933
	118	1937	206	1938	122	1939
	538	1940				
1931	46	1931	81	1933	58	1936
	359	1937	237	1938	640	1939
1932	431	1935	55	1938		
1933	125	1939				
1934	127	1937				
1935	236	1936	515	1937	42	1938
	80	1939	155	1940		
1936	2,037	1937	496	1940		
1937	147	1937				
1938	160	1939	317	1940		
1939	85	1939				
1940	103	1940				

4-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1878	1,996	1,996	0
1881	12,356	2,505	9,851
1883	6,777	2,300	4,477
1884	2,369	1,375	994
1885	3,923	920	3,003
1886	13,085	3,918	9,167
1887	96,867	96,867	0
1888	76,032	25,804	50,228
1889	72,510	53,632	18,878
1890	44,034	6,058	37,976
1891	149,194	119,838	29,356
1892	33,793	0	33,793
1893	26,637	20,344	6,293
1894	6,694	0	6,694
1895	1,080	180	900
1896	7,834	122	7,712
1897	2,181	352	1,829
1898	1,863	1,863	0

Year Installed	Feet Installed	Feet In Service	Feet Retired
1899	8,685	2,797	5,888
1900	2,168	2,138	30
1901	13,190	10,886	2,304
1902	7,577	5,696	1,881
1903	643	643	0
1904	4,986	0	4,986
1905	656	656	0
1906	5,572	657	4,915
1907	3,009	2,274	735
1909	2,597	24	2,573
1910	553	0	553
1911	2,721	0	2,721
1913	426	426	0
1914	137	115	22
1915	36	0	36
1916	53	17	36
1917	27	0	27
1918	4	4	0

4-IN. CAST-IRON UNLINED MAINS (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1919	367	340	27
1920	35	35	0
1921	2,517	2,517	0
1922	328	328	0
1923	470	470	0
1924	422	422	0
1925	52	52	0
1926	943	943	0
1927	258	79	179
1928	979	979	0
1929	231	231	0
1930	256	256	0
1931	64	64	0
1932	9	9	0
1934	177	177	0
1936	62	62	0
1937	117	117	0
1938	67	67	0
1940	92	92	0
TOTAL	619,711	371,647	248,064

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1881	80	1890	244	1891	500	1899
	5,920	1902	2,600	1903	25	1906
	482	1927				
1883	81	1891	550	1902	2,480	1903
	450	1906	916	1926		
1884	446	1902	548	1907		
1885	135	1891	773	1895	480	1902
	1,415	1905	200	1909		
1886	48	1890	95	1891	1,124	1895
	500	1901	500	1902	6,900	1903
1888	1,902	1890	767	1891	1,634	1895
	1,832	1896	3,078	1898	12,234	1899
	2,905	1900	6,269	1901	4,441	1902
	7,027	1903	845	1905	3,109	1906
	2,126	1915	532	1925	732	1926
	795	1928				
1889	150	1890	863	1895	1,080	1899
	440	1900	1,660	1901	2,074	1902
	2,905	1903	565	1905	198	1906
	1,378	1909	325	1910	688	1911
	410	1922	4,806	1928	1,280	1930
	56	1934				
1890	950	1895	260	1896	346	1898
	290	1900	6,880	1901	998	1902
	1,097	1904	4,358	1907	654	1908
	280	1909	4,280	1911	4,390	1912
	1,413	1913	332	1914	68	1915
	847	1916	300	1922	320	1923
	2,220	1924	705	1925	493	1927
	2,688	1928	61	1929	2,528	1930
	183	1931	70	1934	437	1936
	528	1940				
1891	915	1916	3,677	1918	200	1921
	1,415	1924	56	1925	124	1926
	2,096	1927	1,858	1928	6,101	1930
	2,361	1931	7,487	1932	309	1934
	1,306	1938	1,451	1940		
1892	1,672	1895	920	1898	1,800	1901
	400	1902	4,912	1904	3,900	1905
	799	1906	4,391	1907	5,335	1911
	1,866	1917	827	1923	1,042	1924
	5,929	1930				
1893	346	1895	18	1924	1,701	1930
	345	1931	2,160	1932	387	1937
	617	1938	719	1940		
1894	1,302	1922	50	1925	652	1928
	313	1930	4,377	1939		
1895	220	1904	680	1928		
1896	655	1907	426	1926	1,400	1927
	4,588	1929	643	1939		
1897	1,303	1924	526	1939		
1899	3,915	1906	885	1912	988	1929
	100	1938				
1900	30	1927				
1901	424	1912	875	1926	1,005	1928
1902	1,285	1916	29	1925	567	1937
1904	20	1923	9	1924	458	1930
	4,499	1931				
1906	665	1916	1,321	1924	41	1931
	2,888	1939				
1907	623	1924	112	1939		
1909	2,573	1926				
1910	523	1916	30	1932		
1911	2,063	1924	22	1925	608	1931
	28	1938				
1914	22	1940				
1915	36	1926				
1916	36	1931				
1917	27	1928				
1919	27	1940				
1927	179	1937				

6-IN. CAST-IRON UNLINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1878	34,405	34,405	0
1880	68	0	68
1881	9,503	0	9,503
1883	29,209	19,093	10,116
1884	22,615	18,035	4,580
1885	8,442	8,442	0
1886	9,607	7,692	1,915
1887	48,261	48,261	0
1888	35,989	29,124	6,865
1889	36,252	31,166	5,086
1890	434,430	386,768	47,662
1891	66,732	49,711	17,021
1892	149,500	19,963	129,537
1893	10,902	8,373	2,529
1894	50,860	50,395	465
1895	52,613	42,457	10,156
1896	10,566	9,249	1,317
1897	5,517	5,517	0
1898	1,247	1,247	0
1899	17,802	17,025	777
1900	14,976	11,901	3,075
1901	66,572	63,936	2,636
1902	49,447	44,966	4,481
1903	10,279	8,651	1,628
1904	19,910	18,658	1,342
1905	20,506	19,165	1,341
1906	43,373	43,373	0
1907	32,361	32,103	258
1908	11,057	10,868	189
1909	8,695	8,695	0
1910	19,480	18,787	693
1911	41,345	37,538	3,807
1912	32,331	29,424	2,907
1913	29,974	29,371	603
1914	11,473	11,473	0
1915	4,581	4,581	0
1916	37,258	36,823	435
1917	3,041	3,035	6
1918	2,259	2,259	0
1919	16,049	15,657	392
1920	3,618	3,427	191
1921	18,978	18,049	929
1922	44,591	44,562	29
1923	29,630	28,358	1,272
1924	57,635	56,105	1,530
1925	21,453	21,260	193
1926	15,808	15,483	325
1927	33,231	33,019	212
1928	21,900	21,879	21
1929	13,300	13,300	0
1930	22,412	22,141	271
1931	28,346	28,306	40
1932	5,703	5,703	0
1933	3,147	3,147	0
1934	325	325	0
1935	3,459	3,438	21
1936	13,033	13,033	0
1937	15,442	15,442	0
1938	8,859	8,859	0
1939	21,203	21,203	0
1940	23,795	23,795	0
TOTAL	1,915,355	1,638,931	276,424

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1880	68	1932				
1881	36	1895	3,332	1896	480	1900
	4,050	1901	580	1903	1,025	1906
1883	3,840	1894	337	1895	12	1899
	1,660	1901	2,600	1903	1,322	1914
	345	1917				
1884	455	1895	75	1899	4,050	1905
1886	45	1895	1,870	1907		
1888	200	1890	829	1895	2,446	1904
	756	1906	2,634	1920		
1889	1,012	1895	2,350	1901	630	1903
	544	1906	550	1925		
1890	1,525	1895	5,210	1896	154	1898
	669	1900	16,680	1901	6,103	1902
	3,597	1903	73	1905	906	1906
1890	4,755	1907	329	1908	651	1910
	415	1911	28	1913	73	1914
	31	1915	80	1916	24	1917
	523	1920	360	1921	421	1922
	1,339	1923	125	1926	88	1927
	130	1928	256	1929	1,828	1931
	79	1934	467	1935	46	1936
	26	1937	200	1938	471	1939
1891	1,778	1895	4,290	1901	25	1902
	105	1905	118	1906	940	1907
	1,946	1914	80	1915	310	1916
	721	1917	1,993	1918	29	1921
	430	1923	708	1924	683	1925
	350	1926	30	1927	318	1930
	29	1936	630	1938	1,508	1940

6-IN. CAST-IRON UNLINED MAINS (contd.)

Retirements by Years (contd.)

Year Installed	Feet	Year	Feet	Year	Feet	Year
1892	19,686	1895	2,192	1896	8,495	1899
	21,021	1900	46,527	1901	16,040	1902
	5,258	1904	25	1905	455	1906
	328	1911	136	1915	3,283	1922
	1,730	1923	690	1926	2,646	1930
	600	1932	425	1933		
1893	720	1896	35	1925	1,456	1926
	318	1938				
1894	400	1923	65	1924		
1895	1,790	1907	1,622	1913	769	1921
	366	1922	3,164	1923	21	1924
	23	1926	1,352	1927	135	1932
	693	1933	221	1937		
1896	641	1908	676	1939		
1899	522	1906	50	1913	175	1927
	30	1930				
1900	2,090	1907	470	1912	406	1923
	109	1937				
1901	473	1912	375	1923	1,320	1924
	443	1931	25	1932		
1902	24	1904	2,302	1907	340	1913
	1,246	1927	255	1932	232	1933
	52	1935	30	1937		
1903	90	1907	308	1923	200	1924
	55	1929	374	1932	601	1933
1904	320	1907	82	1925	211	1928
	81	1929	563	1931	85	1932

Year Installed	Feet	Year	Feet	Year	Feet	Year
1905	120	1912	355	1923	342	1928
	524	1931				
1907	106	1922	57	1929	95	1931
1908	180	1916	9	1924		
1910	665	1920	28	1931		
1911	880	1912	1,531	1924	1,284	1926
	112	1932				
1912	668	1924	1,309	1927	713	1930
	217	1932				
1913	5	1930	100	1931	498	1932
1916	323	1922	112	1928		
1917	6	1927				
1919	364	1924	28	1926		
1920	56	1920	15	1928	120	1939
1921	912	1931	12	1938	5	1940
1922	29	1928				
1923	287	1923	62	1927	55	1928
	82	1930	692	1932	94	1939
1924	37	1928	165	1930	672	1931
	626	1932	30	1939		
1925	43	1927	22	1930	60	1932
	68	1940				
1926	325	1932				
1927	83	1928	129	1931		
1928	10	1930	11	1931		
1930	76	1932	195	1940		
1931	40	1932				
1935	21	1939				

8-IN. CAST-IRON UNLINED MAINS

Year	Feet			Year	Feet		
Installed	Installed	In Service	Retired	Installed	Installed	In Service	Retired
1881	3,156	3,005	151	1901	114	114	0
1883	5,448	5,448	0	1902	653	627	26
1888	336	336	0	1903	431	431	0
1889	16,422	16,041	381	1904	77	33	44
1890	81,764	66,973	14,791	1906	514	514	0
1891	63,379	54,088	9,291	1907	616	616	0
1892	11,903	11,336	567	1908	442	90	352
1893	5,284	5,167	117	1909	273	273	0
1894	155	155	0	1910	522	448	74
1895	12,805	11,795	1,010	1911	566	566	0
1896	130	130	0	1912	131	131	0
1897	1,276	906	370	1913	2,210	2,210	0
1898	39	39	0	1914	2,440	2,440	0
1899	48	48	0	1915	75	75	0
1900	182	182	0	1916	67	67	0

8-IN. CAST-IRON UNLINED MAINS (contd.)

Year Installed	Feet			Year Installed	Feet		
	Installed	In Service	Retired		Installed	In Service	Retired
1917	79	79	0	1931	46,223	46,223	0
1920	3,072	3,072	0	1932	21,436	21,436	0
1921	1,398	1,398	0	1933	2,169	2,169	0
1922	3,351	3,351	0	1934	553	553	0
1923	276	276	0	1935	962	962	0
1924	5,507	5,507	0	1936	8,020	8,020	0
1926	3,056	3,056	0	1937	3,467	3,467	0
1927	5,576	5,576	0	1938	2,450	2,450	0
1928	9,191	9,055	136	1939	28,616	28,616	0
1929	4,747	4,747	0	1940	22,219	22,219	0
1930	10,250	10,221	29				
				TOTAL	394,076	366,737	27,339

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year	Year Installed	Feet	Year	Feet	Year	Feet	Year
1881	151	1894					1891	232	1922	3,159	1931		
1889	381	1895					1892	475	1904	92	1912		
1890	80	1894	5,465	1895	2,000	1896	1893	117	1936				
	920	1901	668	1902	57	1906	1895	32	1902	481	1904	125	1927
	85	1907	37	1910	61	1911		372	1928				
	204	1915	84	1916	4,636	1922	1897	370	1908				
	46	1924	58	1926	33	1936	1902	26	1933				
	333	1938	24	1940			1904	33	1925	11	1931		
1891	105	1894	1,700	1895	48	1899	1908	62	1916	290	1923		
	32	1901	2,657	1902	750	1904	1910	74	1933				
	161	1905	55	1907	60	1913	1928	118	1931	18	1937		
	54	1914	75	1916	203	1918	1930	29	1938				

10-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet			Year Installed	Feet		
	Installed	In Service	Retired		Installed	In Service	Retired
1881	4,397	4,397	0	1906	1,354	1,354	0
1883	5,113	2,313	2,800	1912	2,661	2,661	0
1887	1,968	1,968	0	1920	32	32	0
1888	6,387	6,387	0	1921	88	0	88
1889	6,863	5,597	1,266	1922	3,832	3,832	0
1890	30,639	24,332	6,307	1924	946	946	0
1891	11,213	9,129	2,084	1927	153	153	0
1892	332	0	332	1929	12	12	0
1893	13,183	8,425	4,758	1931	4	4	0
1894	6,699	6,699	0	1932	156	156	0
1895	3,200	2,815	385	1936	25	25	0
1899	772	772	0	1938	8	8	0
1900	1,364	1,364	0	1940	15	15	0
1901	3,638	3,638	0				
1903	3,484	3,237	247	TOTAL	109,953	91,686	18,267
1904	1,415	1,415	0				

10-IN. CAST-IRON UNLINED MAINS (contd.)

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year	Year Installed	Feet	Year	Feet	Year	Feet	Year
1883	1,120	1898	1,150	1902	530	1906	1891	90	1918				
1889	1,266	1901					1892	332	1911				
1890	4,786	1895	107	1902	57	1903	1893	2,124	1899	2,568	1904	66	1906
	100	1908	1,125	1910	30	1916	1895	385	1922				
	54	1922	48	1938			1903	100	1933	147	1934		
1891	649	1895	1,020	1901	325	1906	1921	88	1940				

12-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet			Year Installed	Feet		
	Installed	In Service	Retired		Installed	In Service	Retired
1881	364	279	85	1937	9,055	9,055	0
1888	21,076	16,530	4,546	1938	10,347	10,269	78
1890	53,744	42,149	11,595	1939	28,806	28,806	0
1891	2,571	2,016	555	1940	15,326	15,326	0
1892	164,774	129,221	35,553				
1894	3,282	3,145	137	TOTAL	695,650	634,447	61,203
1895	4,446	2,706	1,740				
1896	438	438	0				
1898	2,382	2,337	45				
1899	165	165	0				
1901	11,029	9,292	1,737				
1902	13,136	13,082	54				
1904	13,512	12,647	865				
1906	2,556	2,556	0				
1907	36,786	36,786	0				
1908	4,917	4,879	38				
1910	17,476	17,021	455				
1911	27,656	27,277	379				
1912	11,058	11,058	0				
1913	10,856	10,856	0				
1914	644	644	0				
1915	5,919	5,835	84				
1916	9,650	7,945	1,705				
1917	253	17	236				
1918	4,651	4,651	0				
1919	5,311	4,375	936				
1920	20	20	0				
1921	104	0	104				
1922	7,734	7,734	0				
1923	14,030	14,006	24				
1924	38,883	38,883	0				
1925	2,429	2,429	0				
1926	3,714	3,575	139				
1927	21,910	21,910	0				
1928	19,026	19,026	0				
1929	7,597	7,597	0				
1930	25,628	25,562	66				
1931	32,367	32,367	0				
1932	27,914	27,914	0				
1933	703	703	0				
1936	1,405	1,358	47				

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1881	85	1913				
1888	4,486	1890	60	1895		
1889	775	1895	590	1896	1,292	1901
	22	1902	5,488	1903	100	1906
	67	1914	865	1921	375	1924
	285	1925	1,040	1926	77	1927
	28	1929	591	1932		
1891	97	1895	56	1899	230	1909
	85	1925	87	1933		
1892	2,524	1895	2,280	1896	339	1899
	835	1900	9,960	1901	10,223	1902
	9,132	1903	260	1910		
1894	130	1924	7	1932		
1895	1,740	1927				
1898	45	1913				
1901	1,680	1910	57	1925		
1902	54	1912				
1904	865	1914				
1908	38	1939				
1910	455	1925				
1911	379	1933				
1915	84	1931				
1916	1,035	1919	17	1925	653	1936
1917	184	1923	52	1927		
1919	936	1937				
1921	104	1940				
1923	24	1931				
1926	28	1929	111	1938		
1930	66	1940				
1936	47	1940				
1938	78	1940				

14-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1888	550	218	332
1890	20,296	20,139	157
1891	9,319	9,239	80
1892	3,996	3,996	0
1894	272	147	125
1895	95	91	4
1903	132	0	132
1909	36	36	0
1910	8	8	0
1916	62	0	62
1920	20	20	0
1928	54	54	0
1940	0	0	0
Total	34,840	33,948	892

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1888	332	1895				
1890	60	1895	24	1902	50	1911
	23	1932				
1891	80	1894				
1894	125	1932				
1895	4	1925				
1903	132	1907				
1916	62	1925				

15-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1872	6,177	6,177	0
1940	0	0	0
Total	6,177	6,177	0

16-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1887	3,678	3,480	198
1890	37,437	31,033	6,404
1891	12,456	12,373	83
1893	48	48	0
1894	70	70	0
1895	94	17	77
1899	3,769	3,769	0
1901	884	756	128
1903	8,025	5,683	2,342
1904	529	529	0
1906	1,162	1,162	0
1907	2,271	2,271	0

16-in. Cast-Iron Unlined Mains (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1908	3,601	3,551	50
1910	483	483	0
1915	2,251	2,251	0
1917	355	355	0
1918	113	113	0
1919	7,052	6,998	54
1920	2,126	1,830	296
1923	4,424	4,424	0
1924	1,489	1,364	125
1925	28	28	0
1926	1,334	1,334	0
1927	2,542	2,502	40
1931	5,904	5,904	0
1932	40	40	0
1934	62	62	0
1937	406	406	0
1940	8,865	8,865	0
Total	111,498	101,701	9,797

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1887	198	1895				
1890	117	1901	5,770	1902	71	1904
	90	1911	356	1917		
1891	29	1913	54	1925		
1895	77	1925				
1901	128	1922				
1903	2,280	1907	62	1934		
1908	36	1927	14	1937		
1919	54	1932				
1920	296	1940				
1924	125	1933				
1927	40	1933				

18-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1888	140	0	140
1890	15,343	15,153	190
1891	1,759	1,759	0
1901	36	36	0
1907	895	895	0
1908	887	872	15
1914	125	125	0
1923	17	17	0
1924	5,300	5,300	0
1925	45	45	0
1927	47	38	9
1931	1,892	1,892	0
1933	3	3	0

18-IN. CAST-IRON UNLINED MAINS (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1937	22	22	0
1940	0	0	0
TOTAL	26,511	26,157	354

Retirements by Years

Year Installed	Feet	Year
1888	140	1895
1890	190	1914
1908	15	1937
1927	9	1937

20-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1880	500	52	448
1881	4,800	1,452	3,348
1888	2,290	400	1,890
1889	2,376	566	1,810
1890	450	450	0
1891	2,393	480	1,913
1895	125	71	54
1899	6,022	3,791	2,231
1903	1,510	1,160	350
1908	464	388	76
1910	1,545	1,545	0
1920	9,551	9,551	0
1923	31	31	0
1924	9,191	9,174	17
1925	72	72	0
1926	3,930	3,930	0
1927	6	6	0
1937	16	16	0
1938	2,109	2,109	0
1940	0	0	0
TOTAL	47,381	35,244	12,137

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1880	53	1932	395	1934		
1881	986	1894	812	1895	1,100	1903
	450	1913				
1888	1,890	1896				
1889	815	1896	995	1899		
1891	1,913	1899				
1895	47	1925	7	1940		
1899	2,231	1937				
1903	350	1937				
1908	35	1927	41	1940		
1924	17	1939				

24-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1890	19,701	18,137	1,564
1891	1,877	1,877	0
1892	22,250	20,882	1,368
1893	38	38	0
1897	6	6	0
1901	9,240	7,786	1,454
1902	27	27	0
1908	3,569	3,569	0
1910	7,625	7,625	0
1911	84	32	52
1913	486	486	0
1917	249	249	0
1918	3,430	3,430	0
1920	1,838	1,838	0
1922	337	337	0
1923	14,440	14,440	0
1924	10,538	10,538	0
1925	48	48	0
1926	2,976	2,976	0
1927	12,656	12,656	0
1930	65	0	65
1932	6,189	6,169	20
1933	201	201	0
1935	36	36	0
1936	18	18	0
1938	422	422	0
1939	564	564	0
1940	2,122	2,122	0
TOTAL	121,032	116,509	4,523

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1890	530	1906	825	1922	6	1923
	75	1933	20	1934	108	1935
1892	104	1895	105	1900	1,159	1906
1901	1,350	1910	104	1940		
1911	52	1933				
1930	65	1933				
1932	20	1938				

30-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1888	1,517	1,349	168
1890	55	55	0
1903	3,795	3,795	0
1917	15,901	15,901	0
1923	9,178	9,178	0
1924	3,208	3,208	0

30-IN. CAST-IRON UNLINED MAINS (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1925	5,606	5,606	0
1927	14,321	14,055	266
1932	279	279	0
1933	150	150	0
1937	369	369	0
1938	14	14	0
1939	66	66	0
1940	35	35	0
TOTAL	54,494	54,060	434

Retirements by Years

Year Installed	Feet	Year
1888	168	1898
1927	266	1932

36-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1924	4,215	4,215	0
1925	8,733	8,733	0
1927	1,348	1,348	0
1933	264	264	0
1936	41	41	0
1940	0	0	0
TOTAL	14,601	14,601	0

39.37-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1924	2,286	2,286	0
1940	0	0	0
TOTAL	2,286	2,286	0

41.34-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1924	2,483	2,483	0
1940	0	0	0
TOTAL	2,483	2,483	0

42-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1924	64	64	0
1925	70	70	0
1940	9	9	0
TOTAL	143	143	0

48-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1925	166	166	0
1933	84	84	0
1940	0	0	0
TOTAL	250	250	0

24-IN. STEEL MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1911	2,582	2,582	0
1935	101	101	0
1940	80	80	0
TOTAL	2,763	2,763	0

24-IN. WOOD-STAVE MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1889	4,000	0	4,000
1901	2,552	0	2,552
1940	0	0	0
TOTAL	6,552	0	6,552

Retirements by Years

Year Installed	Feet	Year
1889	4,000	1900
1901	2,552	1928

30-IN. OD. STEEL MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1928	2,533	2,533	0
1940	0	0	0
TOTAL	2,533	2,533	0

30-IN. CONCRETE MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1938	13,915	13,915	0
1939	2,947	2,947	0
1940	0	0	0
TOTAL	16,862	16,862	0

30-IN. WOOD-STAVE MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1888	193	0	193
1892	2,320	0	2,320
1940	0	0	0
TOTAL	2,513	0	2,513

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1888	193	1891		
1892	1,200	1910	1,120	1921

42-IN. CONCRETE MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1940	3,169	3,169	0
TOTAL	3,169	3,169	0

46-IN. CONCRETE MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1940	6,968	6,968	0
TOTAL	6,968	6,968	0

30-IN. CAST-IRON UNLINED—CONDUIT NO. 1

Year	Feet		
Installed	Installed	In Service	Retired
1890	17,571	17,279	292
1920	193	193	0
1921	89	89	0
1925	76	76	0
1928	58	58	0
1940	0	0	0
TOTAL	17,987	17,695	292

30-IN. CAST-IRON UNLINED—CONDUIT NO. 1 (contd.)

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1890	68	1920	224	1929

36-IN. CAST-IRON UNLINED—CONDUIT NO. 1

Year	Feet		
Installed	Installed	In Service	Retired
1920	6,920	6,920	0
1940	0	0	0
TOTAL	6,920	6,920	0

30-IN. WOOD-STAVE—CONDUIT NO. 1

Year	Feet		
Installed	Installed	In Service	Retired
1890	91,380	0	91,380
1920	3,626	0	3,626
1921	69	0	69
1925	117	0	117
1928	979	0	979
1940	0	0	0
TOTAL	96,171	0	96,171

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1890	10,691	1920	97	1921	23,750	1922
	20,628	1925	4,032	1928	10,579	1929
	17,039	1930	4,564	1936		
1920	3,626	1936				
1921	69	1936				
1925	117	1936				
1928	979	1936				

30-IN. CAST-IRON UNLINED—CONDUIT NO. 2

Year	Feet		
Installed	Installed	In Service	Retired
1893	128	128	0
1915	64	64	0
1918	272	117	155
1924	24	24	0
1928	40	40	0
1930	251	251	0
1938	11	11	0
1940	0	0	0
TOTAL	790	635	155

30-IN. CAST-IRON UNLINED—CONDUIT NO. 2 (contd.)

Retirements by Years

Year Installed	Feet	Year
1918	155	1940

30-IN. WOOD-STAVE—CONDUIT NO. 2

Year Installed	Feet		
	Installed	In Service	Retired
1893	14,727	0	14,727
1940	0	0	0
TOTAL	14,727	0	14,727

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1893	330	1922	40	1928	600	1934
	13,757	1940				

34-IN. STEEL—CONDUIT NO. 2

Year Installed	Feet		
	Installed	In Service	Retired
1893	892	892	0
1924	3,270	3,270	0
1940	0	0	0
TOTAL	4,162	4,162	0

34-IN. WOOD-STAVE—CONDUIT NO. 2

Year Installed	Feet		
	Installed	In Service	Retired
1893	86,594	38,960	47,634
1922	105	105	0
1923	2,311	2,311	0
1927	640	640	0
1930	384	384	0
1931	368	368	0
1932	400	400	0
1935	250	250	0
1938	1,124	1,124	0
1940	0	0	0
TOTAL	92,176	44,542	47,634

34-IN. WOOD-STAVE—CONDUIT NO. 2 (contd.)

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1893	41	1910	108	1920	2,311	1923
	3,294	1924	640	1927	659	1930
	1,835	1931	400	1932	250	1935
	1,535	1938	4,449	1939	32,112	1940

36-IN. WOOD-STAVE—CONDUIT NO. 2

Year Installed	Feet		
	Installed	In Service	Retired
1903	2,264	0	2,264
1940	0	0	0
TOTAL	2,264	0	2,264

Retirements by Years

Year Installed	Feet	Year
1903	2,264	1940

36-IN. CAST-IRON UNLINED—CONDUIT NO. 2

Year Installed	Feet		
	Installed	In Service	Retired
1903	41	0	41
1940	0	0	0
TOTAL	41	0	41

Retirements by Years

Year Installed	Feet	Year
1903	41	1940

38-IN. CONCRETE LINED TUNNEL—CONDUIT NO. 2

Year Installed	Feet		
	Installed	In Service	Retired
1893	12,336	4,614	7,722
1940	0	0	0
TOTAL	12,336	4,614	7,722

Retirements by Years

Year Installed	Feet	Year
1893	7,722	1940

16-IN. SLIP-JOINT STEEL PIPE—CONDUIT NO. 3

Year Installed	Feet		
	Installed	In Service	Retired
1933	300	300	0
1940	0	0	0
TOTAL	300	300	0

30-IN. WOOD-STAVE—CONDUIT NO. 3

Year Installed	Feet		
	Installed	In Service	Retired
1899	19,519	0	19,519
1924	2,113	2,113	0
1935	156	156	0
1940	0	0	0
TOTAL	21,788	2,269	19,519

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1899	26	1923	19,493	1924

30-IN. CAST-IRON UNLINED—CONDUIT NO. 3

Year Installed	Feet		
	Installed	In Service	Retired
1899	2,898	2,211	687
1919	40	40	0
1921	34	34	0
1923	26	26	0
1924	636	636	0
1940	0	0	0
TOTAL	3,634	2,947	687

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1899	616	1924	71	1926

30-IN. CONCRETE—CONDUIT NO. 3

Year Installed	Feet		
	Installed	In Service	Retired
1939	26,303	26,303	0
1940	0	0	0
TOTAL	26,303	26,303	0

34-IN. WOOD-STAVE—CONDUIT NO. 3

Year Installed	Feet		
	Installed	In Service	Retired
1899	3,900	0	3,900
1940	0	0	0
TOTAL	3,900	0	3,900

Retirements by Years

Years Installed	Feet	Year	Feet	Year
1899	24	1919	3,876	1924

36-IN. WOOD-STAVE—CONDUIT NO. 3

Year Installed	Feet		
	Installed	In Service	Retired
1899	2,822	197	2,625
1940	0	0	0
TOTAL	2,822	197	2,625

Retirements by Years

Year Installed	Feet	Year
1899	2,625	1924

36-IN. CAST-IRON UNLINED—CONDUIT NO. 3

Year Installed	Feet		
	Installed	In Service	Retired
1924	25,576	25,541	35
1926	110	110	0
1940	0	0	0
TOTAL	25,686	25,651	35

Retirements by Years

Year Installed	Feet	Year
1924	35	1932

40-IN. WOOD-STAVE—CONDUIT NO. 3

Year Installed	Feet		
	Installed	In Service	Retired
1899	89,728	0	89,728
1919	2,393	0	2,393
1921	3,168	0	3,168
1925	1,414	64	1,350
1928	1,448	1,448	0

40-IN. WOOD-STAVE—CONDUIT NO. 3 (contd.)

Year	Feet		
Installed	Installed	In Service	Retired
1931	590	590	0
1934	495	495	0
1935	840	840	0
1940	0	0	0
TOTAL	100,076	3,437	96,639

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1899	2,383	1919	3,188	1921	2,445	1924
	25,125	1925	1,448	1927	590	1931
	18,270	1932	495	1934	1,056	1935
	34,728	1939				
1919	2,393	1939				
1921	3,168	1939				
1925	1,350	1939				

42-IN. CAST-IRON UNLINED—CONDUIT NO. 3

Year	Feet		
Installed	Installed	In Service	Retired
1899	440	440	0
1925	101	101	0
1940	0	0	0
TOTAL	541	541	0

36-IN. CAST-IRON UNLINED—CONDUIT NO. 4

Year	Feet		
Installed	Installed	In Service	Retired
1884	1,008	0	1,008
1940	0	0	0
TOTAL	1,008	0	1,008

Retirements by Years

Year Installed	Feet	Year
1884	1,008	1930

40-IN. WOOD-STAVE—CONDUIT NO. 4

Year	Feet		
Installed	Installed	In Service	Retired
1884	8,075	0	8,075
1940	0	0	0
TOTAL	8,075	0	8,075

40-IN. WOOD-STAVE—CONDUIT NO. 4 (contd.)

Retirements by Years

Year Installed	Feet	Year
1884	8,075	1930

48-IN. WOOD-STAVE—CONDUIT NO. 4

Year	Feet		
Installed	Installed	In Service	Retired
1884	5,452	0	5,452
1940	0	0	0
TOTAL	5,452	0	5,452

Retirements by Years

Year Installed	Feet	Year
1884	5,452	1930

30-IN. WOOD-STAVE—CONDUIT NO. 5

Year	Feet		
Installed	Installed	In Service	Retired
1907	25,385	21,285	4,100
1925	791	791	0
1926	1,252	1,252	0
1927	21	21	0
1934	1,120	1,120	0
1935	210	210	0
1940	0	0	0
TOTAL	28,779	24,679	4,100

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1907	791	1925	1,252	1926	697	1927
	30	1932	1,120	1934	210	1935

30-IN. CAST-IRON UNLINED—CONDUIT NO. 5

Year	Feet		
Installed	Installed	In Service	Retired
1907	57	57	0
1927	32	32	0
1932	30	30	0
1940	0	0	0
TOTAL	119	119	0

36-IN. CONCRETE—CONDUIT NO. 5

Year Installed	Feet Installed	Feet In Service	Feet Retired
1907	2,248	2,248	0
1927	644	644	0
1940	0	0	0
TOTAL	2,892	2,892	0

36-IN. CAST-IRON UNLINED—CONDUIT NO. 5

Year Installed	Feet Installed	Feet In Service	Feet Retired
1907	990	990	0
1940	0	0	0
TOTAL	990	990	0

36-IN. WOOD-STAVE—CONDUIT NO. 5

Year Installed	Feet Installed	Feet In Service	Feet Retired
1907	50	50	0
1940	0	0	0
TOTAL	50	50	0

36-IN. CAST-IRON UNLINED—CONDUIT NO. 6

Year Installed	Feet Installed	Feet In Service	Feet Retired
1910	374	374	0
1922	84	84	0
1939	170	170	0
1940	0	0	0
TOTAL	628	628	0

40-IN. WOOD-STAVE—CONDUIT NO. 6

Year Installed	Feet Installed	Feet In Service	Feet Retired
1910	6,105	0	6,105
1940	0	0	0
TOTAL	6,105	0	6,105

Retirements by Years

Year Installed	Feet	Year
1910	6,105	1940

44-IN. WOOD-STAVE—CONDUIT NO. 6

Year Installed	Feet Installed	Feet In Service	Feet Retired
1893	8,517	1,171	7,346
1940	0	0	0
TOTAL	8,517	1,171	7,346

Retirements by Years

Year Installed	Feet	Year
1893	7,346	1940

48-IN. WOOD-STAVE—CONDUIT NO. 6

Year Installed	Feet Installed	Feet In Service	Feet Retired
1910	56,226	0	56,226
1930	126	0	126
1940	0	0	0
TOTAL	56,352	0	56,352

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1910	84	1922	17	1924	255	1927
	4,312	1928	13,303	1930	29	1934
	449	1936	16,955	1939	20,822	1940
1930	121	1932	5	1933		

48-IN. CAST-IRON UNLINED—CONDUIT NO. 6

Year Installed	Feet Installed	Feet In Service	Feet Retired
1910	486	0	486
1924	17	0	17
1927	307	0	307
1930	36	0	36
1934	29	0	29
1940	0	0	0
TOTAL	875	0	875

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1910	139	1928	347	1930
1924	17	1940		
1927	291	1930	16	1940
1930	36	1940		
1934	29	1940		

48-IN. STEEL—CONDUIT NO. 6

Year Installed	Feet Installed	In Service	Retired
1910	1,542	0	1,542
1936	285	0	285
1940	0	0	0
TOTAL	1,827	0	1,827

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1910	100	1928	732	1930	140	1939
	570	1940				
1936	40	1939	245	1940		

48-IN. WOOD-STAVE—CONDUIT NO. 7

Year Installed	Feet Installed	In Service	Retired
1911	52,531	50,463	2,068
1927	706	706	0
1933	274	274	0
1935	750	750	0
1940	338	338	0
TOTAL	54,599	52,531	2,068

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1911	706	1927	274	1933	750	1935
	338	1940				

48-IN. CAST-IRON UNLINED—CONDUIT NO. 7

Year Installed	Feet Installed	In Service	Retired
1911	386	386	0
1940	0	0	0
TOTAL	386	386	0

60-IN. WOOD-STAVE—CONDUIT NO. 8

Year Installed	Feet Installed	In Service	Retired
1911	12,390	11,676	714
1928	100	100	0
1929	455	455	0
1940	138	138	0
TOTAL	13,083	12,369	714

60-IN. WOOD-STAVE—CONDUIT NO. 8 (contd.)

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1911	21	1925	100	1928	455	1929
	138	1940				

60-IN. CAST-IRON UNLINED—CONDUIT NO. 8

Year Installed	Feet Installed	In Service	Retired
1911	67	67	0
1940	0	0	0
TOTAL	67	67	0

60-IN. STEEL—CONDUIT NO. 8

Year Installed	Feet Installed	In Service	Retired
1911	1,112	1,112	0
1925	21	21	0
1940	0	0	0
TOTAL	1,133	1,133	0

72-IN. CONCRETE LINED TUNNEL—CONDUIT NO. 8

Year Installed	Feet Installed	In Service	Retired
1911	66	66	0
1940	0	0	0
TOTAL	66	66	0

36-IN. WOOD-STAVE—CONDUIT NO. 8 EXTENSION

Year Installed	Feet Installed	In Service	Retired
1911	3,697	3,697	0
1940	0	0	0
TOTAL	3,697	3,697	0

36-IN. CAST-IRON UNLINED—CONDUIT NO. 8 EXTENSION

Year Installed	Feet Installed	In Service	Retired
1911	356	356	0
1940	0	0	0
TOTAL	356	356	0

36-IN. WOOD-STAVE—CONDUIT NO. 9

Year Installed	Feet		
	Installed	In Service	Retired
1916	1,208	0	1,208
1918	1,209	0	1,209
1940	0	0	0
TOTAL	2,417	0	2,417

Retirements by Years

Year Installed	Feet	Year
1916	1,208	1937
1918	1,209	1937

36-IN. CAST-IRON UNLINED—CONDUIT NO. 9

Year Installed	Feet		
	Installed	In Service	Retired
1915	106	0	106
1916	152	0	152
1917	41	0	41
1918	85	0	85
1925	28	0	28
1937	43	43	0
1940	0	0	0
TOTAL	455	43	412

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1915	47	1925	41	1936	18	1937
1916	152	1937				
1917	41	1937				
1918	85	1937				
1925	28	1937				

48-IN. WOOD-STAVE—CONDUIT NO. 9

Year Installed	Feet		
	Installed	In Service	Retired
1915	29,498	0	29,498
1917	2,469	0	2,469
1927	700	0	700
1928	468	0	468
1932	200	0	200
1936	2,469	0	2,469
1940	0	0	0
TOTAL	35,804	0	35,804

48-IN. WOOD-STAVE—CONDUIT NO. 9 (contd.)

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1915	1,009	1925	700	1927	468	1928
	200	1932	27,121	1937		
1917	2,469	1936				
1927	700	1937				
1928	468	1937				
1932	200	1937				
1936	2,469	1939				

48-IN. CAST-IRON UNLINED—CONDUIT NO. 9

Year Installed	Feet		
	Installed	In Service	Retired
1915	617	0	617
1917	85	0	85
1918	87	0	87
1936	172	93	79
1940	0	0	0
TOTAL	961	93	868

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1915	172	1936	445	1937
1917	85	1937		
1918	87	1937		
1936	47	1937	32	1939

48-IN. STEEL—CONDUIT NO. 9

Year Installed	Feet		
	Installed	In Service	Retired
1915	1,518	0	1,518
1940	0	0	0
TOTAL	1,518	0	1,518

Retirements by Years

Year Installed	Feet	Year
1915	1,518	1937

54-IN. CONCRETE—CONDUIT NO. 9

Year Installed	Feet Installed	In Service	Retired
1925	986	324	662
1940	0	0	0
TOTAL	986	324	662

Retirements by Years

Year Installed	Feet	Year
1925	986	1939

Note: 324 ft. transferred to conduit No. 19—still in service.

30-IN. STEEL—CONDUIT NO. 10

Year Installed	Feet Installed	In Service	Retired
1929	2,936	0	2,936
1940	0	0	0
TOTAL	2,936	0	2,936

Retirements by Years

Year Installed	Feet	Year
1929	2,936	1940

36-IN. CAST-IRON UNLINED—CONDUIT NO. 10

Year Installed	Feet Installed	In Service	Retired
1921	36	36	0
1924	108	108	0
1940	0	0	0
TOTAL	144	144	0

54-IN. CONCRETE—CONDUIT NO. 10

Year Installed	Feet Installed	In Service	Retired
1921	27,100	27,100	0
1924	20,446	20,446	0
1940	0	0	0
TOTAL	47,546	47,546	0

60-IN. STEEL—CONDUIT NO. 11

Year Installed	Feet Installed	In Service	Retired
1925	46	46	0
1940	0	0	0
TOTAL	46	46	0

66-IN. WOOD-STAVE—CONDUIT NO. 11

Year Installed	Feet Installed	In Service	Retired
1925	52,427	39,830	12,597
1932	1,037	1,037	0
1933	2,810	2,810	0
1934	785	785	0
1935	1,002	1,002	0
1936	1,241	1,241	0
1937	2,076	2,076	0
1938	2,396	2,396	0
1939	600	600	0
1940	650	650	0
TOTAL	65,024	52,427	12,597

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1925	1,037	1932	2,810	1933	785	1934
	1,002	1935	1,241	1936	2,076	1937
	2,396	1938	600	1939	650	1940

66-IN. CONCRETE—CONDUIT NO. 11

Year Installed	Feet Installed	In Service	Retired
1925	260	260	0
1940	0	0	0
TOTAL	260	260	0

66-IN. STEEL—CONDUIT NO. 11

Year Installed	Feet Installed	In Service	Retired
1925	104	104	0
1940	0	0	0
TOTAL	104	104	0

48-IN. STEEL—CONDUIT NO. 12

Year Installed	Feet		
	Installed	In Service	Retired
1925	5,439	5,439	0
1940	0	0	0
TOTAL	5,439	5,439	0

54-IN. STEEL—CONDUIT NO. 12

Year Installed	Feet		
	Installed	In Service	Retired
1925	8,936	8,936	0
1940	0	0	0
TOTAL	8,936	8,936	0

66-IN. STEEL—CONDUIT NO. 12

Year Installed	Feet		
	Installed	In Service	Retired
1925	195	195	0
1940	0	0	0
TOTAL	195	195	0

66-IN. CONCRETE—CONDUIT NO. 12

Year Installed	Feet		
	Installed	In Service	Retired
1925	31,211	31,211	0
1940	0	0	0
TOTAL	31,211	31,211	0

84-IN. CONCRETE—CONDUIT NO. 12

Year Installed	Feet		
	Installed	In Service	Retired
1925	619	619	0
1940	0	0	0
TOTAL	619	619	0

54-IN. CONCRETE—CONDUIT NO. 13

Year Installed	Feet		
	Installed	In Service	Retired
1930	103	103	0
1940	0	0	0
TOTAL	103	103	0

60-IN. CONCRETE—CONDUIT NO. 13

Year Installed	Feet		
	Installed	In Service	Retired
1930	57,722	57,722	0
1940	0	0	0
TOTAL	57,722	57,722	0

66-IN. STEEL—CONDUIT NO. 13

Year Installed	Feet		
	Installed	In Service	Retired
1928	4,521	4,521	0
1930	53	53	0
1940	0	0	0
TOTAL	4,574	4,574	0

16-IN. CAST-IRON UNLINED—CONDUIT NO. 16

Year Installed	Feet		
	Installed	In Service	Retired
1939	1,941	1,941	0
1940	0	0	0
TOTAL	1,941	1,941	0

42-IN. STEEL—CONDUIT NO. 16

Year Installed	Feet		
	Installed	In Service	Retired
1938	45,613	45,613	0
1940	0	0	0
TOTAL	45,613	45,613	0

30-IN. STEEL—CONDUIT NO. 17

Year Installed	Feet		
	Installed	In Service	Retired
1938	631	631	0
1940	0	0	0
TOTAL	631	631	0

36-IN. STEEL—CONDUIT NO. 17

Year Installed	Feet		
	Installed	In Service	Retired
1938	244	244	0
1940	0	0	0
TOTAL	244	244	0

51-IN. OD. STEEL—CONDUIT NO. 17

Year Installed	Feet		
	Installed	In Service	Retired
1938	6,344	6,344	0
1940	0	0	0
TOTAL	6,344	6,344	0

57-IN. OD. STEEL—CONDUIT NO. 17

Year Installed	Feet		
	Installed	In Service	Retired
1938	12,581	12,581	0
1940	0	0	0
TOTAL	12,581	12,581	0

63-IN. OD. STEEL—CONDUIT NO. 17

Year Installed	Feet		
	Installed	In Service	Retired
1938	17,563	17,563	0
1940	0	0	0
TOTAL	17,563	17,563	0

54-IN. CONCRETE—CONDUIT NO. 18

Year Installed	Feet		
	Installed	In Service	Retired
1938	21,280	21,280	0
1940	0	0	0
TOTAL	21,280	21,280	0

42-IN. CONCRETE—CONDUIT NO. 19

Year Installed	Feet		
	Installed	In Service	Retired
1938	20,550	20,550	0
1940	0	0	0
TOTAL	20,550	20,550	0

54-IN. CONCRETE—CONDUIT NO. 19

Year Installed	Feet		
	Installed	In Service	Retired
1925	324	324	0
1940	0	0	0
TOTAL	324	324	0

VALVES

1-IN. VALVES

Year Installed	Number		
	Installed	In Service	Retired
1895	1	1	0
1901	2	1	1
1902	1	1	0
1904	3	2	1
1905	1	0	1
1906	1	1	0
1907	5	2	3
1908	2	2	0
1909	2	1	1
1910	2	1	1
1911	2	1	1
1913	1	0	1
1914	1	1	0
1917	1	0	1
1924	1	1	0
1925	1	1	0
1926	1	1	0
1927	1	1	0
1928	1	1	0
1940	0	0	0
TOTAL	30	19	11

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1901	1	1926				
1904	1	1938				
1905	1	1939				
1907	1	1924	1	1931	1	1935
1909	1	1925				
1910	1	1929				
1911	1	1928				
1913	1	1923				
1917	1	1927				

1¼-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1890	2	0	2
1898	1	1	0
1903	1	1	0
1904	3	0	3
1905	1	0	1
1906	3	0	3
1907	2	1	1
1908	3	3	0
1909	3	0	3
1911	1	1	0
1914	1	1	0
1915	1	1	0
1917	2	2	0
1918	1	1	0
1919	1	1	0
1922	2	2	0
1923	2	0	2
1924	1	0	1
1931	1	1	0
1936	1	1	0
1938	1	1	0
1940	0	0	0
TOTAL	34	18	16

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1890	2	1922				
1904	2	1923	1	1926		
1905	1	1928				
1906	1	1925	1	1926	1	1928
1907	1	1931				
1909	2	1925	1	1940		
1923	1	1930	1	1931		
1924	1	1926				

1½-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1892	2	0	2
1898	1	1	0
1903	1	1	0
1904	2	2	0
1905	2	0	2
1906	2	0	2
1907	4	3	1
1908	8	4	4
1909	4	2	2
1910	7	4	3
1911	1	1	0
1912	4	3	1
1914	1	0	1
1915	1	0	1
1916	1	0	1
1918	1	0	1
1924	10	9	1
1925	2	2	0
1928	2	2	0
1929	1	1	0
1932	2	1	1
1940	1	1	0
TOTAL	60	37	23

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1892	2	1923				
1905	1	1924	1	1929		
1906	1	1926	1	1930		
1907	1	1928				
1908	1	1924	1	1925	1	1928
	1	1930				
1909	1	1926	1	1928		
1910	1	1926	1	1930	1	1936
1912	1	1926				
1914	1	1928				
1915	1	1927				
1916	1	1926				
1918	1	1927				
1924	1	1935				
1932	1	1938				

2-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1890	14	0	14
1891	1	1	0
1892	10	0	10
1893	5	0	5
1894	3	0	3
1896	2	0	2
1897	3	0	3
1898	2	0	2
1902	1	0	1
1903	6	3	3
1904	14	6	8
1905	19	7	12
1906	19	6	13
1907	10	3	7
1908	27	16	11
1909	52	20	32
1910	41	10	31
1911	48	21	27
1912	22	7	15
1913	18	0	18
1914	9	5	4
1915	7	4	3
1916	5	2	3
1917	8	2	6
1918	5	3	2
1919	8	4	4
1920	27	17	10
1921	70	31	39
1922	182	106	76
1923	124	64	60
1924	81	43	38
1925	70	47	23
1926	53	43	10
1927	33	30	3
1928	22	14	8
1929	12	10	2
1930	12	11	1
1931	11	8	3
1932	9	7	2
1933	5	5	0
1934	2	2	0
1935	8	8	0
1936	4	3	1
1937	10	10	0
1938	10	9	1
1939	14	12	2
1940	11	11	0
TOTAL	1,129	611	518

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1890	6	1911	3	1912	3	1923
	1	1924	1	1927		
1892	3	1923	6	1924	1	1933
1893	1	1935	2	1936	2	1937
1894	2	1923	1	1930		
1896	1	1925	1	1929		
1897	3	1923				
1898	1	1911	1	1938		
1902	1	1930				
1903	3	1924				
1904	4	1923	1	1924	1	1927
	1	1931	1	1933		
1905	7	1924	2	1925	1	1930
	1	1932	1	1926		
1906	1	1923	6	1924	1	1927
	1	1929	1	1933	1	1937
	2	1939				
1907	1	1922	1	1923	2	1931
	3	1939				
1908	1	1924	2	1927	4	1930
	3	1931	1	1936		
1909	1	1923	3	1924	2	1925
	5	1926	2	1927	5	1928
1909	2	1929	4	1930	5	1931
	1	1933	2	1937		
1910	4	1923	9	1924	2	1925
	1	1926	3	1927	3	1928
	2	1929	1	1930	1	1931
	1	1932	3	1933	1	1939
1911	3	1913	1	1923	6	1924
	1	1926	6	1927	4	1928
	4	1931	1	1932	1	1940
1912	5	1924	1	1927	2	1930
	4	1931	2	1932	1	1937
1913	1	1923	8	1924	1	1927
	2	1928	2	1930	4	1931
1914	1	1920	1	1931	1	1936
	1	1940				
1915	1	1926	2	1940		
1916	1	1927	1	1931	1	1940
1917	3	1924	1	1927	2	1931
1918	2	1931				
1919	1	1925	1	1926	1	1931
	1	1934				
1920	2	1925	1	1926	1	1928
	2	1929	1	1931	2	1932
	1	1937				

2-IN. VALVES (contd.)

Retirements by Years (contd.)

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1921	1	1923	1	1925	2	1926	1925	2	1927	3	1928	4	1929
	6	1927	8	1928	1	1929		4	1931	4	1932	1	1933
	3	1930	9	1931	1	1932		1	1934	2	1937	1	1938
	1	1933	3	1939	3	1940		1	1939				
1922	4	1923	3	1924	6	1925	1926	2	1929	1	1930	1	1936
	2	1926	14	1927	13	1928		1	1937	5	1940		
	1	1929	5	1930	14	1931	1927	1	1928	1	1930	1	1939
	8	1932	2	1935	1	1937	1928	1	1929	1	1930	2	1931
	3	1939						3	1932	1	1938		
1923	1	1924	7	1925	1	1926	1929	1	1935	1	1939		
	11	1927	12	1928	2	1929	1930	1	1930				
	3	1930	8	1931	3	1933	1931	2	1938	1	1939		
	1	1937	7	1939	4	1940	1932	1	1938	1	1939		
1924	1	1926	4	1927	2	1928	1936	1	1937				
	3	1929	4	1930	9	1931	1938	1	1939				
	2	1932	2	1935	1	1937	1939	2	1939				
	2	1938	2	1939	6	1940							

2½-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired
1907	1	1	0
1911	1	0	1
1939	1	1	0
1940	0	0	0
TOTAL	3	2	1

Retirements by Years

Year Installed	Number	Year
1911	1	1924

3-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1881	14	0	14	1927	51	42	9
1890	1	0	1	1928	91	76	15
1891	2	0	2	1929	46	35	11
1892	1	0	1	1930	47	36	11
1895	2	2	0	1931	16	12	4
1897	1	0	1	1932	20	19	1
1912	1	1	0	1933	15	15	0
1917	1	1	0	1934	14	13	1
1919	1	0	1	1935	22	19	3
1920	1	0	1	1936	37	33	4
1921	4	4	0	1937	37	36	1
1922	17	11	6	1938	31	30	1
1923	63	35	28	1939	34	33	1
1924	78	59	19	1940	35	34	1
1925	60	47	13				
1926	40	29	11	TOTAL	783	622	161

3-IN. VALVES (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1881	1	1912	1	1913	1	1927
	2	1928	4	1929	3	1934
	1	1938	1	1939		
1890	1	1916				
1891	2	1924				
1892	1	1924				
1897	1	1924				
1919	1	1931				
1920	1	1925				
1922	1	1925	1	1927	1	1929
	3	1932				
1923	5	1925	1	1926	10	1927
	3	1928	3	1931	5	1932
	1	1940				
1924	4	1925	4	1928	3	1930
	5	1931	1	1932	1	1933
	1	1940				
1925	1	1925	3	1927	1	1928
	2	1931	2	1933	2	1937
	2	1940				
1926	1	1927	2	1931	6	1932

Year Installed	Number	Year	Number	Year	Number	Year
	2	1940				
1927	1	1928	3	1931	1	1932
	2	1934	1	1936	1	1937
1928	1	1929	2	1930	3	1931
	4	1932	1	1935	1	1937
	1	1938	1	1939	1	1940
1929	2	1930	3	1931	2	1932
	1	1935	1	1937	2	1940
1930	1	1930	3	1932	2	1933
	2	1937	1	1938	1	1939
	1	1940				
1931	1	1933	1	1936	1	1938
	1	1939				
1932	1	1932				
1934	1	1937				
1935	1	1937	1	1939	1	1940
1936	3	1937	1	1940		
1937	1	1937				
1938	1	1940				
1939	1	1939				
1940	1	1940				

4-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired
1881	1	0	1
1883	2	0	2
1888	14	7	7
1889	12	0	12
1890	144	118	26
1891	178	113	65
1892	41	11	30
1893	61	40	21
1894	40	22	18
1895	4	2	2
1896	17	5	12
1897	7	5	2
1898	7	7	0
1899	15	3	12
1900	17	17	0
1901	43	36	7
1902	19	16	3
1903	7	6	1
1904	17	5	12
1905	8	7	1
1906	20	12	8
1907	38	30	8
1908	1	0	1
1909	4	1	3
1910	8	6	2
1911	42	38	4
1913	13	13	0
1914	4	3	1
1915	1	0	1
1916	8	6	2
1917	1	0	1
1918	5	5	0
1919	9	9	0
1920	2	2	0
1921	10	10	0
1922	20	18	2
1923	9	7	2
1924	15	13	2
1925	7	6	1
1926	4	4	0
1927	12	10	2
1928	13	13	0
1929	6	6	0
1930	11	8	3
1931	8	8	0
1932	4	4	0
1934	1	1	0
1935	2	2	0
1936	1	1	0
1937	1	1	0
1938	2	2	0
1939	3	3	0
1940	4	4	0
TOTAL	943	666	277

4-IN. VALVES (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1881	1	1927				
1883	2	1926				
1888	3	1915	1	1925	2	1926
	1	1934				
1889	1	1909	2	1911	1	1922
	7	1928	1	1934		
1890	1	1911	1	1912	1	1913
	1	1916	4	1924	1	1925
	3	1927	5	1928	2	1929
	2	1930	2	1931	2	1934
	1	1936				
1891	1	1909	1	1916	4	1918
	10	1924	1	1926	18	1927
	2	1928	1	1929	7	1930
	7	1931	8	1932	2	1934
	3	1940				
1892	6	1911	4	1923	4	1924
	15	1930	1	1937		
1893	10	1930	1	1931	4	1932
	1	1933	1	1937	1	1938
	3	1940				
1894	2	1922	2	1925	14	1928
1895	2	1928				
1896	1	1924	3	1927	7	1929
	1	1939				
1897	2	1939				
1899	6	1906	3	1912	2	1929
	1	1930				
1901	2	1912	1	1916	1	1926
	3	1928				
1902	2	1916	1	1925		
1903	1	1931				
1904	1	1923	11	1931		
1905	1	1927				
1906	1	1916	2	1924	1	1928
	1	1930	1	1931	2	1939
1907	1	1915	1	1924	6	1934
1908	1	1932				
1909	3	1926				
1910	1	1916	1	1932		
1911	1	1924	1	9125	2	1931
1914	1	1940				
1915	1	1926				
1916	1	1922	1	1931		
1917	1	1928				
1922	2	1932				
1923	1	1928	1	1932		
1924	1	1928	1	1939		
1925	1	1928				
1927	1	1931	1	1937		
1930	2	1931	1	1939		

6-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1880	10	8	2	1898	4	4	0
1881	10	8	2	1899	53	52	1
1883	15	11	4	1900	45	44	1
1884	5	5	0	1901	214	204	10
1885	20	20	0	1902	120	108	12
1886	12	12	0	1903	80	74	6
1888	51	49	2	1904	75	70	5
1889	50	46	4	1905	65	63	2
1890	784	662	122	1906	118	114	4
1891	485	449	36	1907	120	117	3
1892	500	457	43	1908	35	34	1
1893	22	20	2	1909	32	32	0
1894	24	22	2	1910	90	88	2
1895	211	178	33	1911	123	111	12
1896	36	27	9	1912	87	79	8
1897	29	29	0	1913	122	118	4

6-IN. VALVES (contd.)

Year Installed	Number Installed	In Service	Retired
1914	23	23	0
1915	15	15	0
1916	107	104	3
1917	15	15	0
1918	9	9	0
1919	48	46	2
1920	9	8	1
1921	30	25	5
1922	151	149	2
1923	111	102	9
1924	262	252	10
1925	84	80	4
1926	74	72	2
1927	158	155	3
1928	110	110	0
1929	72	72	0
1930	98	92	6
1931	95	95	0
1932	42	42	0
1933	11	11	0
1934	5	5	0
1935	38	38	0
1936	29	29	0
1937	54	54	0
1938	32	32	0
1939	72	72	0
1940	74	74	0
TOTAL	5,475	5,096	379

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1880	2	1932				
1881	1	1934	1	1938		
1883	3	1914	1	1917		
1888	1	1920	1	1935		
1889	4	1925				
1890	33	1902	23	1903	2	1904
	1	1905	6	1907	6	1910
	1	1916	2	1917	1	1921
	17	1922	2	1923	2	1926
	3	1927	4	1929	6	1931
	1	1933	1	1934	1	1935
	1	1936	1	1937	7	1938
	1	1939				
1891	2	1905	3	1907	2	1915
	3	1917	2	1918	2	1923
	4	1924	2	1926	1	1936
	1	1938	14	1940		
1892	21	1901	5	1904	2	1906
	1	1911	3	1922	2	1923
	2	1926	6	1930	1	1938
1893	1	1925	1	1938		
1894	2	1923				
1895	3	1907	2	1908	5	1913
	2	1922	8	1923	1	1926
	2	1927	3	1932	3	1933
	4	1937				
1896	1	1908	8	1939		
1899	1	1927				
1900	1	1912				
1901	2	1912	1	1923	4	1924
	1	1931	1	1932	1	1937
1902	5	1907	1	1913	4	1927
	1	1933	1	1937		
1903	1	1910	1	1923	1	1924
	1	1929	2	1932		
1904	1	1924	1	1929	3	1931
1905	1	1928	1	1931		
1906	1	1927	1	1935	2	1940
1907	2	1929	1	1931		
1908	1	1916				
1910	1	1927	1	1931		
1911	2	1912	5	1924	4	1926
	1	1931				
1912	2	1924	1	1927	4	1930
	1	1932				
1913	4	1931				
1916	2	1928	1	1937		
1919	1	1924	1	1927		
1920	1	1939				
1921	4	1931	1	1940		
1922	1	1928	1	1929		
1923	1	1927	1	1928	2	1931
	3	1932	2	1940		
1924	2	1928	1	1930	4	1931
	3	1939				
1925	1	1930	1	1932	2	1940
1926	1	1931	1	1932		
1927	1	1928	2	1931		
1930	1	1932	1	1939	4	1940

8-IN. VALVES

Year	Number		
Installed	Installed	In Service	Retired
1883	12	11	1
1884	3	3	0
1888	1	1	0
1889	16	16	0
1890	246	226	20
1891	119	109	10
1892	12	11	1
1893	13	13	0
1894	2	2	0
1895	64	60	4
1896	4	4	0
1897	1	1	0
1899	1	1	0
1900	1	1	0
1901	5	5	0
1902	1	1	0
1903	6	6	0
1904	1	0	1
1905	8	7	1
1906	4	4	0
1907	13	13	0
1908	3	2	1
1910	10	10	0
1911	5	5	0
1912	4	4	0
1913	4	4	0
1914	2	2	0
1915	1	1	0
1916	1	1	0
1918	5	5	0
1920	6	6	0
1921	3	3	0
1922	15	13	2
1923	4	4	0
1924	24	24	0
1925	3	3	0
1926	20	19	1
1927	29	29	0
1928	50	49	1
1929	13	12	1
1930	56	54	2
1931	147	147	0
1932	92	92	0
1933	17	17	0
1934	16	16	0
1935	3	2	1
1936	27	27	0
1937	12	12	0
1938	34	34	0
1939	95	95	0
1940	77	77	0
TOTAL	1,311	1,264	47

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1883	1	1934					1904	1	1931				
1890	1	1902	1	1906	1	1907	1905	1	1928				
	1	1910	1	1911	1	1916	1908	1	1923				
	7	1922	2	1924	2	1926	1922	2	1926				
	1	1932	1	1938	1	1940	1926	1	1931				
1891	1	1904	3	1918	1	1922	1928	1	1931				
	1	1924	4	1931			1929	1	1931				
1892	1	1904					1930	1	1938	1	1940		
1895	1	1904	1	1927	1	1928	1935	1	1939				
	1	1933											

10-IN. VALVES

Year	Number		
Installed	Installed	In Service	Retired
1890	103	91	12
1891	35	32	3
1893	7	5	2
1894	10	10	0
1895	17	17	0
1899	2	2	0

10-IN. VALVES (contd.)

Year Installed	Number Installed	Number In Service	Number Retired
1900	2	2	0
1901	10	9	1
1903	2	1	1
1906	3	3	0
1910	1	1	0
1911	2	2	0
1912	10	10	0
1914	1	1	0
1915	4	4	0
1916	2	2	0
1917	1	1	0
1920	7	4	3
1921	1	1	0
1922	12	12	0
1923	4	4	0
1924	8	8	0
1925	2	2	0
1927	5	5	0
1928	1	1	0
1929	1	1	0
1930	2	1	1
1932	1	1	0
1935	3	3	0
1937	1	0	1
1939	1	1	0
1940	2	2	0
TOTAL	263	239	24

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1890	3	1902	2	1903	2	1908
	2	1910	2	1922	1	1939
1891	2	1918	1	1935		
1893	2	1904				
1901	1	1935				
1903	1	1934				
1920	3	1937				
1930	1	1940				
1937	1	1939				

12-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired
1883	5	5	0
1884	4	4	0
1888	6	6	0
1889	10	10	0
1890	110	93	17
1891	50	47	3
1892	260	232	28
1894	3	0	3
1895	16	15	1
1896	3	3	0
1897	1	1	0
1898	5	4	1
1899	3	3	0
1901	30	27	3
1902	17	17	0
1903	5	5	0
1904	20	20	0
1905	1	1	0
1906	7	7	0
1907	66	66	0
1908	20	19	1
1910	44	44	0
1911	75	70	5
1912	32	32	0
1913	24	24	0
1914	2	2	0
1915	6	5	1
1916	30	27	3
1917	10	5	5
1918	10	10	0
1919	16	16	0
1920	12	12	0
1921	1	0	1
1922	32	32	0
1923	55	52	3
1924	133	133	0
1925	14	13	1
1926	15	13	2
1927	71	70	1
1928	63	63	0
1929	35	35	0
1930	84	81	3
1931	105	104	1
1932	85	85	0
1933	2	2	0
1934	1	1	0
1935	1	0	1
1936	10	10	0
1937	28	28	0
1938	44	42	2
1939	87	87	0
1940	51	51	0
TOTAL	1,820	1,734	86

12-IN. VALVES (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1890	11	1903	2	1921	1	1925
	1	1926	1	1927	1	1929
1891	2	1925	1	1933		
1892	14	1902	13	1903	1	1910
1894	3	1924				
1895	1	1927				
1898	1	1913				
1901	3	1925				
1908	1	1927				
1911	5	1933				
1915	1	1931				
1916	2	1919	1	1936		
1917	2	1923	1	1927	2	1939
1921	1	1940				
1923	3	1930				
1925	1	1932				
1926	1	1929	1	1938		
1927	1	1933				
1930	1	1931	2	1940		
1931	1	1940				
1935	1	1939				
1938	2	1940				

14-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1890	40	36	4
1891	14	14	0
1892	2	2	0
1893	1	1	0
1894	2	0	2
1895	2	1	1
1898	1	1	0
1901	2	2	0
1908	1	0	1
1910	1	1	0
1916	1	0	1
1918	2	2	0
1920	2	2	0
1924	2	2	0
1928	1	1	0
1940	0	0	0
TOTAL	74	65	9

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1890	2	1902	1	1911	1	1932
1894	2	1932				
1895	1	1925				
1908	1	1939				
1916	1	1925				

15-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1872	3	3	0
1890	5	5	0
1940	0	0	0
TOTAL	8	8	0

16-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1890	44	38	6
1891	13	12	1
1894	4	4	0
1895	5	5	0
1899	2	2	0
1901	1	1	0
1903	6	6	0
1904	1	1	0
1906	1	1	0
1907	4	4	0
1908	6	6	0
1910	1	1	0
1915	3	3	0
1918	4	4	0
1919	6	6	0
1920	5	5	0
1922	1	1	0
1923	16	16	0
1924	5	5	0
1925	1	1	0
1926	3	3	0
1927	4	2	2
1929	1	0	1
1931	4	4	0
1934	1	1	0
1937	2	2	0
1940	6	6	0
TOTAL	150	140	10

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1890	3	1902	2	1904	1	1917
1891	1	1913				
1927	1	1929	1	1933		
1929	1	1939				

18-in. Valves

Year Installed	Number Installed	Number In Service	Number Retired
1890	22	22	0
1891	3	3	0
1893	1	1	0
1906	1	1	0
1908	1	1	0
1924	5	5	0
1925	3	3	0
1927	2	1	1
1931	3	3	0
1937	1	1	0
1940	0	0	0
Total	42	41	1

Retirements by Years

Year Installed	Number	Year
1927	1	1937

20-in. Valves

Year Installed	Number Installed	Number In Service	Number Retired
1881	4	2	2
1888	1	1	0
1889	1	1	0
1890	1	1	0
1891	1	1	0
1895	2	1	1
1899	4	3	1
1903	2	2	0
1908	1	0	1
1920	10	10	0
1923	1	1	0
1924	8	8	0
1925	3	3	0
1926	4	4	0
1928	1	1	0
1937	2	2	0
1938	2	2	0
1940	0	0	0
Total	48	43	5

Retirements by Years

Year Installed	Number	Year	Number	Year
1881	1	1932	1	1938
1895	1	1925		
1899	1	1937		
1908	1	1940		

24-in. Valves

Year Installed	Number Installed	Number In Service	Number Retired
1890	14	14	0
1891	1	1	0
1892	16	15	1
1893	1	1	0
1895	2	2	0
1896	1	1	0
1901	7	6	1
1903	2	2	0
1908	5	4	1
1910	8	8	0
1911	2	1	1
1913	2	2	0
1914	2	2	0
1917	1	1	0
1918	5	5	0
1920	1	1	0
1923	13	13	0
1924	13	13	0
1925	2	2	0
1926	3	3	0
1927	13	13	0
1928	2	2	0
1929	1	0	1
1930	2	0	2
1932	4	4	0
1933	3	3	0
1936	1	1	0
1937	1	1	0
1938	14	14	0
1939	5	5	0
1940	3	3	0
Total	150	143	7

Retirements by Years

Year Installed	Number	Year	Number	Year
1892	1	1906		
1901	1	1928		
1908	1	1925		
1911	1	1923		
1929	1	1940		
1930	1	1932	1	1938

30-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired
1888	1	1	0
1891	2	1	1
1903	2	2	0
1912	1	1	0
1917	2	2	0
1923	10	10	0
1924	3	3	0
1925	7	7	0
1927	7	7	0
1929	1	1	0
1932	1	1	0
1933	2	2	0
1936	6	6	0
1940	0	0	0
TOTAL	45	44	1

Retirements by Years

Year Installed	Number	Year
1891	1	1902

36-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired
1924	4	4	0
1925	11	11	0
1927	3	3	0
1933	2	2	0

36-IN. VALVES (contd.)

Year Installed	Number Installed	Number In Service	Number Retired
1936	1	1	0
1940	1	1	0
TOTAL	22	22	0

42-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired
1924	1	1	0
1925	1	0	1
1940	2	2	0
TOTAL	4	3	1

Retirements by Years

Year Installed	Number	Year
1925	1	1937

48-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired
1925	2	2	0
1933	2	2	0
1940	0	0	0
TOTAL	4	4	0

HYDRANTS AND APPURTENANCES

4-IN. HYDRANTS

Year Installed	Number Installed	Number In Service	Number Retired
1885	1	0	1
1889	19	0	19
1890	100	57	43
1891	91	58	33
1892	40	25	15
1893	85	54	31
1894	90	54	36
1895	6	2	4
1896	4	2	2
1897	1	1	0
1899	8	5	3
1900	1	0	1
1901	27	12	15
1902	14	9	5
1903	2	0	2
1904	1	1	0
1905	5	5	0
1906	15	5	10
1907	6	4	2
1909	2	2	0
1910	1	1	0
1911	28	26	2
1912	2	1	1
1913	1	1	0
1915	10	9	1
1916	1	1	0
1917	1	0	1
1918	1	0	1

4-IN. HYDRANTS (contd.)

Year Installed	Number Installed	In Service	Retired	Year Installed	Number Installed	In Service	Retired
1919	3	0	3	1929	2	2	0
1921	1	0	1	1930	14	14	0
1922	1	0	1	1931	5	4	1
1923	2	0	2	1932	2	2	0
1924	1	0	1	1936	1	1	0
1925	5	2	3	1938	1	1	0
1926	2	2	0	1940	3	3	0
1927	2	1	1				
1928	4	2	2	TOTAL	612	369	243

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1885	1	1909					1896	2	1926				
1889	1	1911	2	1915	1	1922	1899	3	1928				
	1	1923	1	1926	2	1927	1900	1	1927				
	4	1928	5	1932	2	1936	1901	1	1923	3	1925	1	1928
1890	7	1915	1	1922	3	1923		1	1929	1	1930	5	1931
	1	1925	1	1926	4	1927		1	1932	1	1933	1	1938
	5	1928	11	1930	2	1931	1902	3	1931	1	1932	1	1937
	5	1932	1	1934	1	1939	1903	1	1919	1	1923		
	1	1940					1906	4	1930	1	1938	5	1939
1891	3	1918	7	1924	1	1927	1907	1	1932	1	1939		
	1	1928	6	1931	3	1932	1911	1	1928	1	1933		
	1	1933	5	1934	1	1935	1912	1	1928				
	1	1936	1	1937	3	1940	1915	1	1928				
1892	1	1906	3	1923	2	1927	1917	1	1928				
	4	1929	2	1930	3	1931	1918	1	1936				
1893	1	1915	1	1923	1	1926	1919	3	1927				
	6	1927	4	1928	1	1929	1921	1	1929				
	10	1930	2	1931	1	1932	1922	1	1930				
	1	1937	1	1938	2	1940	1923	1	1924	1	1931		
1894	4	1922	4	1923	1	1924	1924	1	1932				
	1	1925	2	1926	9	1928	1925	1	1928	1	1932	1	1940
	1	1929	2	1930	6	1931	1927	1	1928				
	3	1932	2	1939	1	1940	1928	2	1940				
1895	2	1923	1	1929	1	1936	1931	1	1940				

6-IN. HYDRANTS

Year Installed	Number Installed	In Service	Retired	Year Installed	Number Installed	In Service	Retired
1889	251	250	1	1899	35	34	1
1890	557	535	22	1900	14	14	0
1891	1,116	1,061	55	1901	179	176	3
1892	9	6	3	1902	93	91	2
1893	17	14	3	1903	20	19	1
1894	46	34	12	1904	31	31	0
1895	143	140	3	1905	42	41	1
1896	19	19	0	1906	97	92	5
1897	4	4	0	1907	80	77	3
1898	3	3	0	1908	8	8	0

6-IN. HYDRANTS (contd.)

Year Installed	Number Installed	In Service	Retired	Year Installed	Number Installed	In Service	Retired
1909	5	5	0	1926	34	34	0
1910	11	11	0	1927	114	113	1
1911	30	30	0	1928	108	107	1
1912	3	3	0	1929	80	78	2
1913	41	40	1	1930	106	105	1
1914	4	4	0	1931	159	158	1
1915	7	7	0	1932	122	122	0
1916	13	12	1	1933	15	15	0
1917	15	15	0	1934	8	8	0
1918	6	5	1	1935	13	13	0
1919	24	23	1	1936	24	24	0
1920	10	9	1	1937	21	20	1
1921	41	39	2	1938	17	17	0
1922	110	109	1	1939	34	34	0
1923	98	96	2	1940	23	23	0
1924	156	156	0				
1925	82	82	0	TOTAL	4,298	4,166	132

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1889	1	1915					1903	1	1938				
1890	1	1906	2	1915	2	1923	1905	1	1928				
	1	1927	2	1929	3	1930	1906	1	1928	1	1930	1	1931
	3	1931	1	1932	1	1935		1	1937	1	1940		
	1	1936	1	1937	1	1938	1907	1	1926	1	1929	1	1940
	3	1939					1913	1	1913				
1891	3	1914	1	1915	1	1923	1916	1	1932				
	3	1926	4	1927	1	1929	1918	1	1930				
	3	1930	4	1931	5	1932	1919	1	1927				
	5	1933	4	1935	1	1936	1920	1	1937				
	6	1937	6	1938	4	1939	1921	1	1930	1	1931		
	4	1940					1922	1	1927				
1892	1	1927	1	1930	1	1935	1923	1	1927	1	1939		
1893	1	1923	1	1932	1	1937	1927	1	1939				
1894	8	1922	1	1928	1	1932	1928	1	1940				
	1	1937	1	1938			1929	1	1937	1	1940		
1895	1	1933	1	1937	1	1938	1930	1	1939				
1899	1	1930					1931	1	1933				
1901	1	1923	1	1931	1	1935	1937	1	1940				
1902	1	1929	1	1933									

4-IN. CAST-IRON HYDRANT BRANCHES

Year Installed	Number Installed	In Service	Retired	Year Installed	Number Installed	In Service	Retired
1889	270	131	139	1895	66	34	32
1890	600	445	155	1896	36	4	32
1891	1,089	832	257	1897	24	24	0
1892	800	623	177	1898	10	10	0
1893	492	143	349	1899	86	35	51
1894	1,500	955	545	1900	225	188	37

4-IN. CAST-IRON HYDRANT BRANCHES (contd.)

Year Installed	Number Installed	In Service	Retired	Year Installed	Number Installed	In Service	Retired
1901	323	202	121	1921	12	4	8
1902	175	128	47	1922	8	8	0
1903	49	41	8	1923	48	14	34
1904	51	51	0	1924	21	15	6
1905	48	48	0	1925	42	6	36
1906	197	106	91	1927	18	18	0
1907	92	71	21	1928	78	78	0
1909	6	6	0	1929	4	4	0
1911	70	64	6	1930	44	44	0
1912	30	30	0	1931	5	5	0
1915	12	12	0	1937	42	42	0
1916	24	24	0	1940	3	3	0
1917	8	0	8				
1919	25	0	25	TOTAL	6,633	4,448	2,185

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year	Year Installed	Feet	Year	Feet	Year	Feet	Year
1889	25	1923	6	1926	24	1927	1896	28	1926	4	1933		
	4	1928	54	1932	26	1936	1899	51	1928				
1890	36	1923	40	1927	24	1928	1900	37	1928				
	9	1931	23	1932	23	1937	1901	35	1923	39	1925	10	1928
1891	86	1924	12	1927	8	1932		25	1931	12	1932		
	51	1934	23	1935	5	1936	1902	26	1931	9	1932	12	1937
	14	1937	8	1939	50	1940	1903	8	1923				
1892	83	1923	18	1928	41	1930	1906	37	1930	54	1939		
	24	1931	11	1932			1907	10	1932	11	1939		
1893	32	1923	4	1926	63	1927	1911	6	1928				
	85	1928	29	1929	86	1930	1917	8	1928				
	9	1931	6	1932	12	1937	1919	25	1927				
	4	1938	19	1940			1921	8	1929				
1894	148	1922	34	1923	10	1924	1923	24	1924	10	1931		
	9	1925	22	1926	106	1928	1924	6	1932				
	46	1931	51	1932	88	1938	1925	7	1928	10	1930	10	1932
	31	1939						9	1940				
1895	25	1923	7	1929									

6-IN. CAST-IRON HYDRANT BRANCHES

Year Installed	Number Installed	In Service	Retired	Year Installed	Number Installed	In Service	Retired
1889	2,012	2,004	8	1901	1,284	1,207	77
1890	6,191	5,824	367	1902	1,065	1,042	23
1891	17,076	16,073	1,003	1903	439	429	10
1892	94	60	34	1904	354	354	0
1893	242	187	55	1905	323	258	65
1894	552	530	22	1906	1,112	997	115
1895	1,878	1,769	109	1907	811	736	75
1896	144	95	49	1908	74	74	0
1897	46	46	0	1909	57	57	0
1898	156	156	0	1910	151	85	66
1899	486	453	33	1911	309	309	0
1900	235	235	0	1912	22	22	0

6-IN. CAST-IRON HYDRANT BRANCHES (contd.)

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1913	1,064	1,020	44	1928	1,141	1,141	0
1914	323	323	0	1929	784	784	0
1915	216	216	0	1930	1,069	1,058	11
1916	123	123	0	1931	1,899	1,899	0
1917	411	411	0	1932	1,292	1,247	45
1918	59	56	3	1933	42	42	0
1919	182	166	16	1934	167	167	0
1920	121	102	19	1935	83	83	0
1921	379	379	0	1936	297	297	0
1922	1,224	1,190	34	1937	285	285	0
1923	1,098	1,043	55	1938	241	241	0
1924	1,771	1,745	26	1939	534	534	0
1925	952	952	0	1940	452	452	0
1926	531	531	0				
1927	1,447	1,442	5	TOTAL	53,300	50,931	2,369

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year	Year Installed	Feet	Year	Feet	Year	Feet	Year
1889	8	1932					1901	40	1924	18	1927	10	1931
1890	60	1914	41	1915	6	1917		9	1939				
	6	1922	90	1923	8	1925	1902	23	1927				
	33	1927	22	1928	22	1931	1903	10	1932				
	31	1932	12	1934	14	1938	1905	53	1914	12	1928		
	22	1940					1906	69	1914	12	1917	9	1926
1891	18	1913	74	1914	29	1915		4	1927	7	1931	14	1937
	19	1917	67	1918	9	1921	1907	52	1926	23	1929		
	97	1924	68	1925	95	1926	1910	55	1920	11	1931		
	133	1927	61	1928	80	1930	1913	30	1914	14	1940		
	100	1931	45	1932	6	1933	1918	3	1936				
	16	1937	57	1938	20	1939	1919	16	1927				
	9	1940					1920	19	1937				
1892	34	1926					1922	8	1924	7	1925	9	1930
1893	8	1914	32	1923	15	1926		10	1931				
1894	15	1928	7	1932			1923	23	1926	22	1927	10	1932
1895	8	1914	60	1915	8	1920	1924	10	1927	16	1934		
	30	1922	3	1926			1927	5	1928				
1896	27	1924	22	1939			1930	11	1939				
1899	16	1928	17	1930			1932	45	1934				

4-IN. HYDRANT VALVES

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1889	8	0	8	1896	4	2	2
1890	61	39	22	1897	1	1	0
1891	60	41	19	1899	9	6	3
1892	9	0	9	1900	17	13	4
1893	41	17	24	1901	36	27	9
1894	42	8	34	1902	15	11	4
1895	14	11	3	1903	2	2	0

4-IN. HYDRANT VALVES (contd.)

Year Installed	Number		
	Installed	In Service	Retired
1904	10	8	2
1905	4	4	0
1906	21	12	9
1907	22	17	5
1908	2	2	0
1909	1	1	0
1910	8	8	0
1911	33	32	1
1912	4	3	1
1913	1	1	0
1915	10	10	0
1916	6	5	1
1917	1	0	1
1919	5	2	3
1921	1	0	1
1922	4	3	1
1923	3	1	2
1924	7	4	3
1925	5	2	3
1926	2	2	0
1927	1	0	1
1928	4	4	0
1929	4	3	1
1930	11	10	1
1931	2	2	0
1932	4	4	0
1934	1	1	0
1937	1	1	0
1938	1	1	0
1940	0	0	0
TOTAL	498	321	177

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1889	1	1911	2	1923	1	1926
	1	1927	1	1928	2	1932
1890	1	1916	2	1923	1	1925
	4	1927	2	1928	12	1930
1891	1	1916	3	1918	2	1924
	1	1927	1	1930	2	1932
	5	1934	1	1935	1	1936
	2	1940				
1892	1	1906	1	1923	2	1928
	4	1930	1	1931		
1893	1	1923	6	1927	4	1928
	1	1929	7	1930	1	1931
	1	1932	1	1937	1	1938
	1	1940				
1894	3	1922	4	1923	1	1924
	1	1925	2	1926	8	1928
	1	1930	6	1931	3	1932
	2	1938	3	1939		
1895	1	1929	1	1932	1	1933
1896	1	1926	1	1933		
1899	3	1928				
1900	1	1928	2	1932	1	1936
1901	1	1923	3	1925	1	1928
	2	1931	1	1932	1	1937
1902	2	1931	1	1932	1	1937
1904	1	1928	1	1932		
1906	4	1930	5	1939		
1907	2	1931	3	1932		
1911	1	1928				
1912	1	1928				
1916	1	1928				
1917	1	1928				
1919	3	1927				
1921	1	1929				
1922	1	1930				
1923	1	1924	1	1931		
1924	1	1926	1	1927	1	1932
1925	1	1928	1	1932	1	1940
1927	1	1931				
1929	1	1931				
1930	1	1934				

6-IN. HYDRANT VALVES

Year Installed	Number		
	Installed	In Service	Retired
1889	251	248	3
1890	473	445	28
1891	976	890	86
1892	9	3	6
1893	15	12	3
1894	46	42	4

6-IN. HYDRANT VALVES (contd.)

Year Installed	Number Installed	Number In Service	Number Retired
1895	170	160	10
1896	22	19	3
1897	4	4	0
1898	5	5	0
1899	34	22	12
1900	18	18	0
1901	185	176	9
1902	95	95	0
1903	38	37	1
1904	44	44	0
1905	47	45	2
1906	109	105	4
1907	97	94	3
1908	8	8	0
1909	7	7	0
1910	24	24	0
1911	30	30	0
1912	3	3	0
1913	73	71	2
1914	20	20	0
1915	7	7	0
1916	13	13	0
1917	15	15	0
1918	8	6	2
1919	30	28	2
1920	13	11	2
1921	42	41	1
1922	117	114	3
1923	124	122	2
1924	175	173	2
1925	98	97	1
1926	56	56	0
1927	133	133	0
1928	123	123	0
1929	91	91	0
1930	110	110	0
1931	189	189	0
1932	147	144	3
1933	13	13	0
1934	21	21	0
1935	10	10	0
1936	27	27	0
1937	28	28	0
1938	29	29	0
1939	31	31	0
1940	34	34	0
TOTAL	4,487	4,293	194

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1889	2	1928	1	1932		
1890	1	1906	1	1915	1	1917
	2	1923	2	1925	4	1928
	1	1930	4	1931	4	1932
	1	1934	2	1936	1	1937
	1	1938	3	1939		
1891	3	1914	1	1915	1	1917
	1	1918	1	1923	6	1924
	6	1925	4	1926	7	1927
	12	1928	1	1929	9	1930
	7	1931	2	1932	5	1933
	1	1934	2	1936	7	1937
	7	1938	2	1939	1	1940
1892	1	1923	3	1926	2	1933
1893	1	1923	1	1926	1	1936
1894	2	1928	1	1934	1	1937
1895	1	1915	1	1928	3	1931
	2	1932	1	1935	1	1936
	1	1937				
1896	1	1933	1	1938	1	1939
1899	1	1926	8	1928	1	1930
	1	1936	1	1938		
1901	7	1922	1	1927	1	1931
1903	1	1937				
1905	1	1914	1	1928		
1906	1	1914	1	1931	1	1934
	1	1937				
1907	1	1926	2	1929		
1913	2	1914				
1918	1	1930	1	1936		
1919	2	1927				
1920	2	1937				
1921	1	1927				
1922	1	1925	1	1930	1	1931
1923	1	1926	1	1927		
1924	1	1927	1	1934		
1925	1	1931				
1932	3	1934				

LEAD SERVICES

¾-IN. LEAD SERVICES

Year Installed	Number Installed	In Service	Retired	Year Installed	Number Installed	In Service	Retired
1875	1	0	1	1890	488	333	155
1881	14	9	5	1891	783	625	158
1882	77	71	6	1892	876	681	195
1883	19	11	8	1893	772	617	155
1884	63	50	13	1894	348	276	72
1885	139	130	9	1895	364	304	60
1886	126	108	18	1896	214	161	53
1887	399	399	0	1940	0	0	0
1888	211	210	1				
1889	227	215	12	TOTAL	5,121	4,200	921

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1875	1	1924					1891	4	1919	12	1920	7	1921
1881	1	1907	1	1925	1	1927		4	1922	9	1923	6	1924
	1	1928	1	1930				4	1925	3	1926	2	1927
1882	1	1905	1	1911	1	1912		1	1928	2	1929	3	1930
	1	1929	1	1930	1	1937		6	1931	1	1932	5	1933
1883	1	1905	2	1913	1	1914		1	1934	8	1935	2	1936
	1	1915	1	1917	1	1918		3	1937	1	1938	4	1939
	1	1919						1	1940				
1884	1	1903	1	1908	1	1911	1892	2	1906	1	1907	8	1908
	1	1912	1	1913	1	1917		6	1909	5	1910	6	1911
	1	1921	1	1922	2	1923		7	1912	2	1913	3	1914
	2	1925	1	1926				5	1915	11	1916	2	1917
1885	1	1905	1	1917	1	1918		8	1918	4	1919	9	1920
	1	1924	1	1927	1	1930		4	1921	11	1922	10	1923
	1	1931	1	1935	1	1937		8	1924	6	1925	5	1926
1886	1	1909	3	1910	1	1914		3	1927	7	1928	7	1929
	1	1915	2	1916	1	1920		7	1930	4	1931	6	1932
	2	1922	4	1924	1	1925		5	1933	4	1934	5	1935
	1	1935	1	1937				7	1936	5	1937	4	1938
1888	1	1936						4	1939	4	1940		
1889	1	1909	1	1911	1	1917	1893	2	1903	2	1906	3	1907
	1	1922	1	1925	1	1928		4	1908	2	1909	8	1910
	1	1930	1	1932	1	1934		2	1911	4	1912	2	1913
	2	1935	1	1936				4	1914	8	1915	2	1916
1890	1	1902	1	1905	1	1906		1	1917	2	1918	4	1919
	5	1908	2	1909	3	1910		4	1920	2	1921	3	1922
	6	1911	6	1912	2	1913		5	1923	7	1924	10	1925
	3	1914	4	1915	11	1916		6	1926	9	1927	3	1928
	1	1918	4	1919	4	1920		6	1929	9	1930	6	1931
	6	1921	7	1922	7	1923		5	1932	4	1933	2	1934
	10	1924	4	1925	8	1926		4	1935	2	1936	5	1937
	4	1927	3	1928	8	1929		10	1939	3	1940		
	16	1930	7	1931	5	1932	1894	3	1904	2	1905	1	1906
	3	1933	2	1934	5	1935		2	1908	2	1909	4	1910
	2	1936	2	1937	2	1938		3	1911	3	1912	2	1913
1891	1	1907	2	1908	6	1909		2	1915	2	1918	1	1919
	9	1910	8	1911	11	1912		1	1920	1	1921	4	1922
	6	1913	2	1914	9	1915		4	1923	1	1924	1	1925
	8	1916	5	1917	2	1918		1	1927	3	1928	2	1929

½-IN. LEAD SERVICES (contd.)

Retirements by Years (contd.)

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1894	3	1930	4	1931	2	1932	1895	1	1936	4	1937	2	1938
	5	1933	3	1934	2	1935		4	1939	1	1940		
	4	1936	1	1937	3	1938	1896	3	1907	5	1908	4	1909
1895	2	1900	2	1903	1	1904		1	1910	1	1911	4	1912
	2	1905	3	1908	3	1910		1	1913	2	1914	1	1915
	1	1911	2	1912	1	1913		1	1916	1	1917	1	1918
	2	1914	1	1917	3	1918		1	1922	2	1923	2	1924
	1	1919	2	1920	1	1923		2	1925	1	1927	2	1928
	3	1924	2	1925	2	1926		3	1929	3	1930	3	1931
	1	1927	2	1928	2	1929		1	1933	2	1935	1	1936
	1	1930	1	1931	1	1932		4	1937	1	1938		
	2	1933	2	1934	2	1935							

⅝-IN. LEAD SERVICES

Year Installed	Number			Year Installed	Number		
	Installed	In Service	Retired		Installed	In Service	Retired
1875	115	106	9	1909	1,350	1,324	26
1876	85	79	6	1910	1,121	1,103	18
1877	69	64	5	1911	991	971	20
1878	190	179	11	1912	651	643	8
1879	348	326	22	1913	381	380	1
1880	414	397	17	1914	253	252	1
1881	505	477	28	1915	229	229	0
1882	354	325	29	1916	182	181	1
1883	271	251	20	1917	136	132	4
1884	183	161	22	1918	114	110	4
1885	233	212	21	1919	220	218	2
1886	236	208	28	1920	210	210	0
1887	130	130	0	1921	443	438	5
1888	1,139	1,080	59	1922	593	582	11
1889	1,538	1,417	121	1923	670	666	4
1890	2,071	1,848	223	1924	953	950	3
1891	1,363	1,139	224	1925	948	948	0
1892	1,010	899	111	1926	508	506	2
1893	700	609	91	1927	397	397	0
1894	247	222	25	1928	296	295	1
1895	372	331	41	1929	205	204	1
1896	279	252	27	1930	115	115	0
1897	360	360	0	1931	149	149	0
1898	400	400	0	1932	85	85	0
1899	615	615	0	1933	23	23	0
1900	568	512	56	1934	18	18	0
1901	953	891	62	1935	50	50	0
1902	912	852	60	1936	73	73	0
1903	889	860	29	1937	104	104	0
1904	1,030	972	58	1938	84	84	0
1905	918	843	75	1939	128	128	0
1906	1,085	1,032	53	1940	150	150	0
1907	1,060	992	68				
1908	1,189	1,163	26	TOTAL	33,661	31,922	1,739

⅝-IN. LEAD SERVICES (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1875	1	1907	2	1913	1	1915
	1	1919	2	1925	1	1929
	1	1931				
1876	1	1905	1	1913	1	1924
	1	1926	1	1931	1	1937
1877	1	1909	1	1918	1	1925
	2	1928				
1878	1	1906	1	1909	1	1912
	2	1915	1	1923	2	1928
	1	1931	1	1937	1	1939
1879	1	1905	2	1906	1	1911
	1	1912	1	1915	1	1920
	1	1921	1	1923	1	1925
	1	1928	2	1929	2	1930
	3	1931	1	1933	1	1935
	1	1936	1	1937		
1880	1	1905	2	1906	1	1908
	1	1910	1	1912	1	1913
	1	1924	2	1925	1	1927
	1	1928	3	1932	1	1937
	1	1938				
1881	2	1905	1	1907	1	1908
	1	1912	2	1913	1	1914
	1	1916	2	1917	1	1919
	2	1921	1	1922	2	1924
	2	1925	1	1927	1	1931
	4	1932	1	1934	1	1938
	1	1939				
1882	1	1906	1	1907	1	1909
	1	1911	1	1912	1	1913
	1	1915	1	1923	1	1924
	4	1925	2	1926	3	1927
	1	1928	5	1929	1	1931
	1	1935	1	1936	2	1937
1883	1	1905	1	1913	1	1918
	1	1919	2	1921	2	1924
	2	1925	2	1926	2	1927
	1	1929	1	1930	1	1931
	1	1933	1	1938	1	1941
1884	1	1905	3	1906	1	1908
	2	1909	1	1910	1	1916
	3	1917	1	1923	3	1924
	1	1925	1	1926	1	1927
	1	1930	1	1933	1	1938
1885	1	1906	2	1907	2	1915
	1	1918	1	1919	2	1922
	1	1923	1	1924	1	1925
	1	1926	1	1930	2	1931
	1	1932	1	1933	1	1937
	1	1938	1	1939		
1886	1	1905	2	1906	1	1908
	1	1909	1	1910	1	1911
	2	1912	1	1914	1	1915
1886	1	1916	1	1919	1	1920
	2	1921	1	1922	1	1923
	2	1924	2	1925	2	1927
	1	1930	1	1933	1	1936
	1	1938				
1888	2	1919	3	1920	3	1921
	5	1922	3	1923	1	1924
	2	1925	7	1926	3	1927
	2	1928	1	1929	5	1930
	8	1931	2	1933	1	1935
	1	1937	2	1938	5	1939
	3	1940				
1889	1	1907	1	1915	1	1917
	12	1920	3	1921	8	1922
	14	1923	3	1924	3	1925
	2	1926	3	1927	11	1928
	8	1929	9	1930	11	1931
	1	1932	3	1933	2	1934
	5	1935	2	1937	8	1938
	9	1939	1	1940		
1890	3	1905	3	1906	2	1907
	3	1908	2	1909	3	1910
	4	1912	5	1913	1	1914
	2	1915	2	1916	2	1917
	2	1919	4	1920	5	1921
	16	1922	15	1923	10	1924
	14	1925	14	1926	10	1927
	6	1928	6	1929	15	1930
	14	1931	10	1932	4	1933
	7	1935	8	1936	1	1937
	1	1938	9	1939	14	1940
	6	1941				
1891	1	1905	3	1906	1	1907
	2	1908	5	1910	4	1911
	2	1912	2	1914	3	1915
	2	1916	2	1917	3	1918
	3	1919	7	1920	13	1921
	7	1922	10	1923	10	1924
	15	1925	14	1926	12	1927
	6	1928	7	1929	16	1930
	10	1931	4	1932	11	1933
	3	1934	5	1935	7	1936
	6	1937	7	1938	15	1939
	5	1940	1	1941		
1892	1	1909	1	1913	1	1915
	1	1917	1	1919	2	1920
	7	1921	5	1922	4	1923
	6	1924	11	1925	7	1926
	7	1927	3	1928	3	1929
	5	1930	5	1931	5	1932
	5	1933	2	1934	2	1936
	8	1937	3	1938	10	1939
	3	1940	3	1941		

⅝-IN. LEAD SERVICES (contd.)

Retirements by Years (contd.)

Year Installed	Number	Year	Number	Year	Number	Year
1893	2	1905	1	1907	1	1909
	1	1910	1	1913	1	1915
	2	1919	2	1920	1	1921
	4	1922	5	1923	9	1924
	5	1925	8	1926	6	1927
	4	1928	2	1929	7	1930
	4	1931	2	1932	4	1933
	3	1934	2	1935	1	1936
	2	1937	5	1939	3	1940
	3	1941				
1894	1	1910	1	1914	1	1917
	1	1923	2	1924	2	1926
	1	1927	2	1928	1	1929
	3	1930	3	1931	4	1932
	1	1936	1	1937	1	1939
1895	2	1905	1	1909	1	1911
	2	1912	1	1919	1	1920
	1	1922	1	1923	2	1924
	2	1925	1	1928	2	1929
	1	1930	1	1932	3	1934
	1	1935	3	1937	4	1938
	9	1939	2	1940		
1896	1	1905	2	1906	1	1909
	1	1920	1	1921	1	1922
	1	1924	1	1928	1	1929
	1	1930	2	1931	5	1934
	6	1935	1	1936	2	1937
1900	1	1905	1	1906	1	1908
	1	1909	1	1910	1	1911
	2	1913	1	1914	1	1916
	1	1917	2	1918	4	1922
	1	1923	2	1924	3	1925
	3	1926	5	1927	2	1928
	2	1929	4	1930	2	1931
	1	1932	1	1933	1	1934
	1	1935	1	1936	1	1937
	3	1938	4	1939	1	1940
	1	1941				
1901	1	1905	1	1906	1	1910
	1	1912	1	1914	1	1917
	1	1919	5	1920	2	1921
	2	1922	1	1923	2	1924
	1	1925	3	1927	2	1928
	2	1929	2	1930	4	1931
	6	1932	6	1933	8	1935
	3	1936	2	1937	1	1938
	2	1939	1	1940		
1902	1	1905	1	1908	2	1910
	1	1911	1	1912	1	1914
	1	1916	1	1917	1	1920
	1	1923	1	1924	1	1925
	1	1926	3	1927	1	1928
	3	1930	7	1931	2	1932
	3	1933	3	1934	1	1935
	5	1936	6	1937	5	1938
	4	1939	2	1940	1	1941
1903	1	1915	1	1917	2	1922
	3	1923	2	1924	1	1926
	1	1928	2	1929	3	1930
	2	1931	1	1932	1	1933
	1	1934	2	1935	1	1936
	1	1937	1	1938	1	1939
	1	1940	1	1941		
1904	2	1908	1	1910	2	1911
	4	1912	1	1913	1	1918
	2	1920	1	1921	3	1922
	3	1923	2	1924	2	1925
	4	1926	3	1927	2	1929
	3	1930	3	1931	3	1932
	2	1933	1	1935	3	1936
	2	1937	3	1938	4	1939
	1	1940				
1905	1	1910	1	1911	3	1912
	3	1918	2	1919	3	1922
	4	1923	6	1924	5	1925
	1	1926	2	1927	3	1928
	3	1929	5	1930	3	1933
	6	1934	3	1935	2	1936
	8	1937	2	1938	5	1939
	3	1940	1	1941		
1906	1	1908	1	1911	1	1915
	1	1919	1	1920	1	1922
	9	1924	2	1925	2	1926
	2	1927	1	1928	4	1929
	6	1930	3	1932	2	1933
	1	1934	1	1935	2	1936
	2	1937	3	1938	4	1939
	3	1940				
1907	2	1908	3	1911	2	1914
	1	1923	3	1924	1	1925
	2	1926	2	1927	3	1928
	3	1929	4	1930	4	1931
	6	1932	4	1933	3	1934
	1	1935	2	1936	2	1937
	5	1938	5	1939	6	1940
	4	1941				
1908	1	1920	1	1923	2	1924
	1	1926	3	1927	2	1928
	1	1929	1	1930	2	1931
	3	1932	2	1935	1	1936
	2	1937	3	1938	1	1939
1909	3	1913	1	1915	1	1923
	1	1924	1	1927	1	1928
	3	1929	5	1930	1	1934
	1	1935	1	1937	3	1938
	1	1939	3	1940		

⅝-IN. LEAD SERVICES (contd.)

Retirements by Years (contd.)

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1910	1	1913	1	1921	2	1923	1917	1	1931	1	1935	1	1938
	5	1924	1	1925	1	1928		1	1939				
	1	1930	1	1931	1	1932	1918	1	1924	2	1936	1	1939
	1	1933	1	1939	2	1940	1919	1	1923	1	1925		
1911	1	1912	1	1914	1	1915	1921	1	1922	1	1926	1	1927
	6	1924	1	1926	2	1928		1	1931	1	1938		
	1	1929	2	1930	2	1935	1922	4	1924	1	1928	1	1929
	1	1936	1	1938	1	1939		1	1930	1	1938	3	1939
1912	1	1920	1	1923	1	1924	1923	1	1924	2	1930	1	1940
	1	1929	1	1930	1	1931	1924	1	1924	1	1938	1	1940
	1	1940	1	1941			1926	1	1939	1	1940		
1913	1	1923					1928	1	1938				
1914	1	1935					1929	1	1930				
1916	1	1924											

¾-IN. LEAD SERVICES

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1875	14	14	0	1909	841	823	18
1876	2	2	0	1910	808	791	17
1877	6	6	0	1911	695	679	16
1878	9	8	1	1912	519	515	4
1879	23	22	1	1913	300	300	0
1880	35	34	1	1914	236	236	0
1881	31	31	0	1915	204	199	5
1882	30	30	0	1916	220	220	0
1883	17	14	3	1917	189	185	4
1884	11	10	1	1918	181	177	4
1885	18	18	0	1919	432	328	4
1886	48	44	4	1920	501	500	1
1887	49	49	0	1921	1,439	1,432	7
1888	320	256	64	1922	2,227	2,196	31
1889	418	336	82	1923	2,186	2,166	20
1890	533	383	150	1924	2,208	2,194	14
1891	341	227	114	1925	2,188	2,183	5
1892	224	146	78	1926	1,498	1,493	5
1893	163	98	65	1927	1,281	1,272	9
1894	59	35	24	1928	1,105	1,102	3
1895	120	80	40	1929	750	748	2
1896	102	67	35	1930	423	423	0
1897	71	71	0	1931	523	516	7
1898	92	92	0	1932	341	340	1
1899	134	134	0	1933	179	178	1
1900	132	122	10	1934	209	209	0
1901	251	222	29	1935	409	407	2
1902	241	227	14	1936	670	667	3
1903	275	264	11	1937	768	766	2
1904	338	327	11	1938	805	805	0
1905	391	354	37	1939	1,228	1,227	1
1906	389	364	25	1940	1,992	1,992	0
1907	475	453	22				
1908	904	885	19	TOTAL	33,821	32,794	1,027

¾-IN. LEAD SERVICES (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1878	1	1928				
1879	1	1930				
1880	1	1928				
1883	2	1926	1	1927		
1884	1	1928				
1886	1	1908	1	1910	1	1928
	1	1940				
1888	5	1907	2	1908	1	1909
	3	1910	2	1911	2	1913
	4	1914	2	1915	3	1916
	1	1917	1	1918	2	1920
	4	1921	1	1922	4	1923
	4	1924	2	1925	5	1926
	2	1927	5	1930	2	1931
	3	1932	1	1937	1	1938
	1	1939	1	1940		
1889	1	1902	1	1903	1	1905
	2	1906	4	1907	7	1908
	5	1909	3	1910	5	1911
	4	1912	2	1913	2	1914
	2	1916	2	1917	1	1920
	2	1921	1	1922	3	1924
	4	1925	4	1926	2	1927
	2	1928	2	1929	3	1930
	2	1931	3	1932	1	1933
	1	1934	3	1935	2	1936
	2	1938	3	1939		
1890	1	1901	1	1902	1	1904
	4	1905	3	1906	7	1907
	6	1908	5	1909	4	1910
	5	1911	2	1912	3	1913
	2	1914	2	1915	2	1916
	4	1917	6	1919	8	1920
	2	1921	6	1922	3	1923
	6	1924	6	1925	5	1926
	6	1927	4	1928	6	1929
	9	1930	2	1931	6	1932
	2	1933	3	1934	2	1935
	4	1936	2	1937	2	1938
	5	1939	3	1940		
1891	5	1903	4	1904	1	1905
	4	1906	2	1907	9	1908
	1	1909	4	1910	2	1911
	1	1912	9	1913	1	1914
	3	1915	2	1916	2	1917
	1	1918	2	1919	1	1920
	5	1922	3	1923	9	1924
	3	1925	2	1926	4	1927
	2	1929	7	1930	3	1931
	2	1932	1	1933	1	1934
	1	1935	2	1936	3	1937
	1	1938	10	1939	1	1940

Year Installed	Number	Year	Number	Year	Number	Year
1892	1	1903	1	1904	1	1905
	3	1906	1	1907	2	1908
	2	1909	3	1911	4	1912
	2	1914	2	1916	2	1917
	2	1920	3	1921	2	1922
	4	1923	4	1924	2	1925
	5	1926	2	1927	1	1928
	5	1929	5	1930	3	1931
	2	1932	1	1933	1	1934
	4	1936	2	1937	3	1938
	3	1939				
1893	1	1901	1	1902	1	1903
	2	1904	1	1905	4	1906
	2	1907	1	1908	1	1910
	2	1912	2	1913	1	1916
	2	1918	4	1920	3	1922
	1	1923	2	1924	3	1925
	4	1926	1	1927	3	1928
	1	1929	2	1930	2	1931
	5	1932	2	1933	2	1934
	1	1935	4	1937	2	1939
	2	1940				
1894	2	1904	1	1906	1	1907
	2	1908	1	1909	1	1911
	1	1920	1	1922	1	1923
	2	1928	2	1931	5	1932
	1	1933	1	1936	1	1937
	1	1938				
1895	1	1904	3	1905	1	1908
	1	1909	2	1910	3	1914
	3	1920	1	1922	3	1924
	3	1925	4	1927	1	1928
	1	1929	2	1932	1	1933
	3	1934	4	1935	2	1936
	1	1939				
1896	1	1903	2	1906	2	1907
	1	1908	3	1909	1	1910
	3	1912	1	1913	1	1916
	1	1920	1	1922	1	1923
	4	1924	1	1925	1	1927
	2	1928	1	1930	1	1931
	1	1933	1	1934	1	1935
	2	1936	2	1937		
1900	1	1921	1	1924	1	1925
	3	1926	2	1927	1	1928
	1	1935				
1901	2	1922	2	1925	1	1926
	2	1928	1	1929	1	1930
	1	1931	1	1932	1	1933
	3	1934	2	1936	3	1937
	1	1938	7	1939	1	1940

¾-in. Lead Services (contd.)

Retirements by Years (contd.)

Year Installed	Number	Year	Number	Year	Number	Year
1902	1	1920	1	1921	1	1922
	1	1924	2	1925	1	1926
	1	1928	2	1929	2	1930
	1	1932	1	1937		
1903	1	1907	1	1916	2	1918
	1	1919	1	1922	1	1924
	1	1926	1	1930	2	1940
1904	1	1910	1	1917	2	1923
	1	1924	2	1926	1	1928
	1	1931	1	1936	1	1940
1905	1	1915	2	1916	3	1925
	1	1926	2	1927	4	1928
	4	1929	1	1930	1	1931
	3	1932	3	1933	2	1934
	2	1935	1	1936	2	1938
	3	1939	2	1940		
1906	2	1911	2	1914	1	1922
	2	1923	2	1924	2	1925
	1	1927	2	1928	1	1929
	2	1930	2	1933	1	1936
	3	1937	1	1938	1	1940
1907	1	1907	1	1909	1	1913
	1	1914	1	1924	2	1925
	1	1926	1	1927	2	1929
	1	1933	3	1934	1	1935
	1	1936	1	1937	2	1938
	2	1939				
1908	1	1910	1	1919	1	1922
	4	1924	1	1925	2	1926
	1	1927	1	1928	1	1929
	1	1931	1	1932	1	1937
	1	1939	2	1940		
1909	1	1923	2	1924	1	1925
	1	1927	1	1928	1	1929
	3	1930	2	1932	1	1933
	1	1935	1	1937	2	1938
	1	1939				
1910	1	1916	3	1923	1	1925
	2	1926	1	1927	1	1929
	1	1930	1	1933	1	1935
	1	1936	1	1937	2	1938
	1	1940				
1911	2	1922	2	1924	1	1925
	3	1927	1	1928	1	1929
1911	1	1930	1	1936	1	1937
	1	1939	2	1940		
1912	1	1924	1	1926	1	1933
	1	1939				
1915	2	1924	1	1925	1	1928
	1	1939				
1917	1	1922	1	1926	1	1928
	1	1938				
1918	1	1924	1	1925	2	1940
1919	1	1927	1	1934	1	1937
	1	1938				
1920	1	1936				
1921	1	1924	1	1925	1	1928
	1	1930	1	1931	1	1935
	1	1938				
1922	1	1923	6	1924	1	1925
	1	1926	1	1927	1	1928
	1	1929	1	1930	4	1931
	3	1934	1	1935	1	1936
	5	1939	4	1940		
1923	4	1924	2	1928	1	1929
	3	1930	1	1934	4	1936
	1	1936	1	1937	1	1939
	2	1939				
1924	3	1924	1	1925	2	1928
	2	1930	1	1932	2	1936
	1	1937	1	1939	1	1940
1925	1	1926	1	1929	2	1935
	1	1940				
1926	2	1928	1	1932	1	1935
	1	1940				
1927	1	1930	1	1931	4	1935
	1	1937	2	1940		
1928	1	1932	1	1937	1	1938
1929	1	1933	1	1936		
1931	1	1933	1	1935	1	1938
	1	1937	3	1938		
1932	1	1936				
1933	1	1940				
1935	1	1939	1	1940		
1936	1	1936	1	1938	1	1940
1937	2	1939				
1939	1	1940				

1-in. Lead Services

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1875	1	1	0	1910	62	62	0
1877	5	5	0	1911	28	26	2
1878	6	6	0	1912	27	27	0
1880	1	1	0	1913	9	8	1
1881	5	5	0	1914	2	2	0
1882	8	8	0	1915	14	14	0
1883	6	6	0	1916	21	21	0
1884	5	5	0	1917	11	11	0
1885	18	18	0	1918	5	5	0
1886	13	13	0	1919	16	16	0
1887	15	15	0	1920	27	26	1
1888	15	7	8	1921	23	23	0
1889	98	90	8	1922	22	22	0
1890	170	153	17	1923	27	27	0
1891	94	83	11	1924	33	32	1
1892	79	58	21	1925	28	28	0
1893	69	59	10	1926	17	17	0
1894	24	13	11	1927	24	24	0
1895	31	28	3	1928	46	46	0
1896	28	23	5	1929	41	41	0
1897	3	3	0	1930	13	13	0
1898	31	31	0	1931	24	24	0
1899	65	65	0	1932	11	11	0
1900	55	51	4	1933	2	2	0
1901	106	100	6	1934	13	13	0
1902	47	45	2	1935	22	22	0
1903	67	62	5	1936	43	43	0
1904	32	29	3	1937	51	51	0
1905	35	31	4	1938	26	26	0
1906	53	48	5	1939	47	47	0
1907	51	46	5	1940	60	60	0
1908	71	69	2				
1909	62	62	0	Total	2,164	2,029	135

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1888	1	1905	2	1906	1	1909	1890	1	1905	1	1906	1	1907
	1	1910	2	1915	1	1923		1	1908	1	1912	1	1914
1889	1	1910	1	1911	1	1913		1	1916	1	1917	1	1918
	1	1916	2	1920	1	1921		1	1927	1	1930	1	1932
	1	1922						5	1940				

1-IN. LEAD SERVICES (contd.)

Retirements by Years (contd.)

Year Installed	Number	Year	Number	Year	Number	Year
1891	3	1912	1	1918	1	1921
	1	1923	1	1926	2	1928
	1	1933	1	1938		
1892	3	1906	1	1911	2	1914
	1	1922	2	1924	3	1926
	2	1927	1	1929	1	1935
	3	1937	1	1938	1	1939
1893	2	1905	1	1913	2	1920
	1	1922	1	1928	1	1929
	2	1940				
1894	1	1907	1	1911	1	1918
	1	1921	1	1925	1	1928
	1	1933	1	1938	2	1939
	1	1940				
1895	1	1927	1	1931	1	1933
1896	1	1907	1	1909	1	1920
	1	1922	1	1934		
1900	1	1921	1	1937	1	1938
	1	1939				

Year Installed	Number	Year	Number	Year	Number	Year
1901	1	1922	1	1928	1	1930
	1	1932	1	1939	1	1940
1902	1	1928	1	1938		
1903	1	1929	2	1932	1	1936
	1	1940				
1904	1	1925	2	1932		
1905	1	1927	1	1928	1	1937
	1	1939				
1906	1	1926	1	1927	1	1936
	1	1934	1	1938		
1907	1	1926	1	1930	1	1935
	2	1938				
1908	1	1932	1	1936		
1911	1	1922	1	1925		
1913	1	1935				
1920	1	1923				
1924	1	1929				

1¼-IN. LEAD SERVICES

Year Installed	Number Installed	In Service	Retired
1887	2	2	0
1896	1	1	0
1898	4	4	0
1899	4	4	0
1900	4	4	0
1901	12	12	0
1902	8	6	2
1903	19	19	0
1904	8	7	1
1905	10	10	0
1906	15	10	5
1907	8	5	3
1908	7	7	0
1909	15	15	0
1910	17	16	1
1911	6	6	0
1912	5	5	0
1914	2	2	0
1915	2	2	0
1916	3	3	0
1917	5	5	0
1919	5	5	0
1920	5	5	0
1921	2	2	0
1922	8	8	0
1923	10	10	0
1924	10	10	0
1925	13	13	0

Year Installed	Number Installed	In Service	Retired
1926	8	8	0
1927	15	15	0
1928	22	22	0
1929	11	11	0
1930	4	4	0
1931	4	4	0
1932	1	1	0
1933	2	2	0
1934	1	1	0
1935	1	1	0
1936	2	2	0
1937	8	8	0
1938	9	9	0
1939	10	10	0
1940	4	4	0
TOTAL	312	300	12

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1902	2	1938				
1904	1	1911				
1906	1	1926	1	1935	1	1938
	1	1937	1	1938		
1907	2	1922	1	1936		
1910	1	1919				

1½-IN. LEAD SERVICES

Year Installed	Number Installed	In Service	Retired
1888	15	15	0
1889	27	27	0
1890	26	26	0
1891	21	18	3
1892	35	34	1
1893	21	21	0
1894	5	5	0
1896	4	4	0
1897	5	5	0
1898	10	10	0
1899	5	5	0
1900	30	25	5
1901	46	46	0
1902	29	24	5
1903	8	7	1
1904	3	2	1
1905	11	9	2
1906	6	5	1
1907	11	11	0
1908	12	12	0
1909	12	10	2
1910	13	10	3
1911	9	8	1
1912	3	3	0
1913	2	2	0
1914	4	4	0
1915	2	2	0
1916	3	3	0
1917	5	4	1
1919	4	3	1
1920	3	3	0
1921	2	2	0
1922	9	9	0
1923	5	5	0
1924	16	15	1
1925	9	9	0
1926	3	3	0
1927	2	2	0
1928	7	7	0
1929	8	8	0
1930	4	4	0
1931	2	2	0
1932	1	1	0
1933	1	1	0
1935	2	2	0
1936	3	3	0
1937	6	6	0
1938	4	4	0
1939	4	4	0
1940	2	2	0
TOTAL	480	452	28

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1891	1	1908	1	1911	1	1927
1892	1	1920				
1900	1	1919	1	1920	1	1927
	1	1932	1	1934		
1902	2	1923	1	1926	2	1936
1903	1	1928				
1904	1	1937				
1905	1	1926	1	1938		

Year Installed	Number	Year	Number	Year	Number	Year
1906	1	1927				
1909	2	1930				
1910	1	1929	1	1932	1	1934
1911	1	1930				
1917	1	1933				
1919	1	1932				
1924	1	1940				

2-IN. LEAD SERVICES

Year Installed	Number Installed	In Service	Retired
1881	1	1	0
1882	1	1	0
1884	1	1	0
1887	6	6	0
1892	17	16	1
1893	30	29	1
1894	8	4	4
1896	4	4	0
1901	2	1	1
1902	2	2	0
1903	3	3	0
1905	4	4	0
1906	3	2	1
1907	4	4	0
1908	2	2	0
1909	7	5	2
1910	3	3	0
1911	1	1	0

2-IN. LEAD SERVICES (contd.)

Year Installed	Number		
	Installed	In Service	Retired
1912	2	2	0
1913	5	5	0
1914	1	1	0
1917	3	3	0
1918	1	1	0
1919	1	1	0
1920	3	3	0
1921	1	1	0
1922	2	2	0
1923	2	2	0
1924	5	5	0
1925	2	2	0
1926	2	2	0
1928	1	1	0
1930	1	1	0
1931	2	2	0
1933	1	1	0
1935	1	1	0
1936	2	2	0
1937	3	3	0
1938	3	3	0
1940	1	1	0
TOTAL	144	134	10

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1892	1	1925				
1893	1	1924				
1894	1	1911	1	1925	1	1929
	1	1930				
1901	1	1933				
1906	1	1917				
1909	1	1928	1	1932		

3-IN. LEAD SERVICES

Year Installed	Number		
	Installed	In Service	Retired
1900	1	0	1
1901	2	0	2
1916	1	1	0
1917	1	1	0
1918	2	2	0
1919	2	1	1
1921	2	2	0
1922	1	1	0
1923	3	3	0
1924	5	5	0
1925	2	2	0
1931	1	1	0
1938	2	2	0
1940	1	1	0
TOTAL	26	22	4

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1900	1	1928				
1901	1	1932	1	1936		
1919	1	1932				

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

BACTERIOLOGY

Relative Resistance of *Escherichia coli* and *Eberthella typhosa* to Chlorine and Chloramines. ELSIE WATTIE & C. T. BUTTERFIELD. Pub. Health Rpts. **59**: 52: 1661 (Dec. 29, '44). In course of studies on influence of pH and temp. on bactericidal properties of chlorine for coliforms and enteric pathogens, noted that relative resistance, or susceptibility, of *Esch. coli* and *Eber. typhosa* appeared to shift as pH of suspending water changed. This phenomenon investigated further by making addnl. observations at other hydrogen-ion concns. in zone of apparent shift in resistance and by repeating tests with other bact. strains. In addn., study repeated, using chloramine as disinfecting agent instead of free chlorine. Data presented showing relative resistance of *Eber. typhosa* and *Esch. coli* strains to free chlorine and chloramine in waters held at 20° to 25°C. and buffered at pH 6.5, 7.0, 7.8, 8.5, 9.5 and 10.5. Each point plotted on charts (Figs. 1–6) represents avg. of from 2 to 8 detns. under conditions given. Although statistical anal. of results not within scope of report, study made of differences between individual observations, with particular reference to (1) variations in resistance of same strains in different tests, (2) variations in resistance between different strains, and (3) routine observational errors. Results with free chlorine indicated that (1) at pH 6.5 and 7.0 typhosa strains consistently more resistant than coli strains, (2) at pH 7.8 coli strains more resistant with concns. of free chlorine in excess of about 0.03 ppm., and (3) at pH 8.5 or above all strains of *Esch. coli* tested consistently as resistant, and usually more resistant, to free chlorine than any *Eber. typhosa* strains. Consequently, while range of probable error does not permit definite allocation of pH, between 7.0 and 8.5, where "change-over" in sensitivity occurs, consistency of results at pH 6.5 and 7.0, and at pH 8.5 or above, leaves no doubt as to existence of "change-over." "Change-over" in sensitivity with increasing pH marked by condition that *Esch. coli* required greater increases in chlorine concn. than *Eber. typhosa* to produce equiv. kills. Although factual information not available to support theory, would seem that cells of *Eber. typhosa* might become more sensitive to free chlorine with increasing pH, due to some function of their capsular substance. Perhaps capsular substance less permeable to chlorine at lower pH values. If true, then more heavily encapsulated *Eber. typhosa* would be more resistant under such conditions. When chloramine used as bactericidal agent, only slight differences observed in sensitivity of 2 genera studied. In few instances *Esch. coli* more resistant to chloramine than *Eber. typhosa*, particularly at pH 7.8 and 10.5, but in general about equally sensitive. Pronounced difference in bactericidal properties of chlorine and chloramine should also be noted. At normal pH values approx. 40 times more residual chlorine as chloramine required to produce 100% kill of *Esch. coli* in same time interval. For *Eber. typhosa* this ratio about 25 to 1. On basis of time required to produce 100% kill with equiv. amts. of residual chlorine, as free chlorine, and as chloramine, results not readily obtainable for lower pH zones. In this range lethal amts. of free chlorine much less than amt. of chloramine required to produce 100% kill in any reasonable period (4–6 hr.). At pH 9.5, where such comparisons possible, chloramine required approx. 100-fold period for free chlorine.—*Ed.*

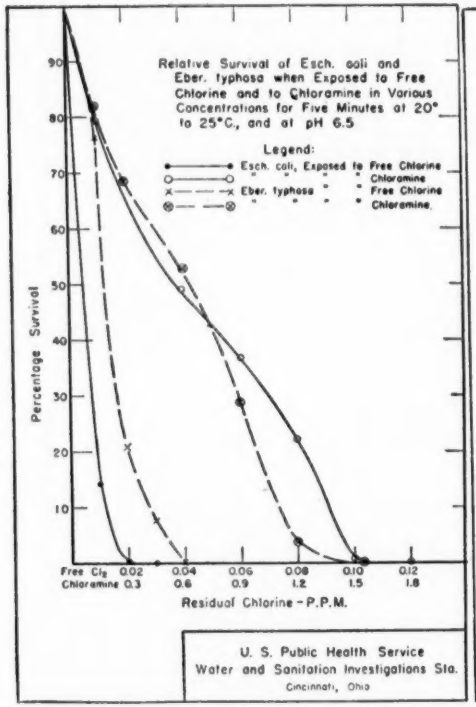
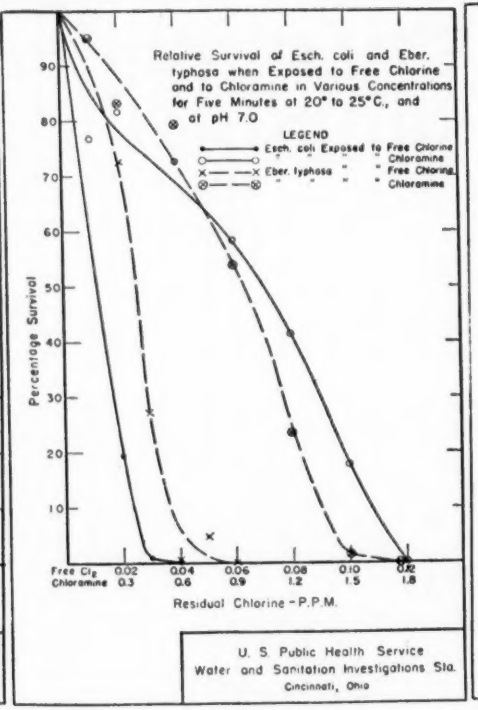

Relative Survival of Esch. coli and Eber. typhosa when Exposed to Free Chlorine and to Chloramine in Various Concentrations for Five Minutes at 20° to 25°C., and at pH 6.5
Legend:
Esch. coli, Exposed to Free Chlorine
" " " " Chloramine
Eber. typhosa " " Free Chlorine
" " " " Chloramine.
Percentage Survival
Free Cl2 0.02 0.04 0.06 0.08 0.10 0.12
Chloramine 0.3 0.6 0.9 1.2 1.5 1.8
Residual Chlorine - P.P.M.
U. S. Public Health Service
Water and Sanitation Investigations Sta.
Cincinnati, Ohio

FIG. 1


Relative Survival of Esch. coli and Eber. typhosa when Exposed to Free Chlorine and to Chloramine in Various Concentrations for Five Minutes at 20° to 25°C., and ⊗ at pH 7.0
LEGEND
Esch. coli Exposed to Free Chlorine
" " " " Chloramine
Eber. typhosa " " Free Chlorine
" " " " Chloramine
Percentage Survival
Free Cl2 0.02 0.04 0.06 0.08 0.10 0.12
Chloramine 0.3 0.6 0.9 1.2 1.5 1.8
Residual Chlorine - P.P.M.
U. S. Public Health Service
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Cincinnati, Ohio

FIG. 2

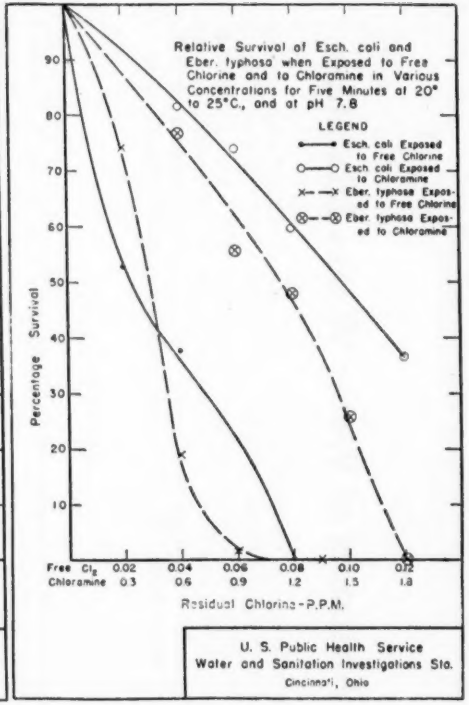
Relative Survival of Esch. coli and Eber. typhosa when Exposed to Free Chlorine and to Chloramine in Various Concentrations for Five Minutes at 20° to 25°C., and at pH 7.8
LEGEND
Esch. coli Exposed to Free Chlorine
Esch. coli Exposed to Chloramine
Eber. typhosa Exposed to Free Chlorine
Eber. typhosa Exposed to Chloramine
Percentage Survival
Free Cl2 0.02 0.04 0.06 0.08 0.10 0.12
Chloramine 0.3 0.6 0.9 1.2 1.5 1.8
Residual Chlorine - P.P.M.
U. S. Public Health Service
Water and Sanitation Investigations Sta.
Cincinnati, Ohio

FIG. 3

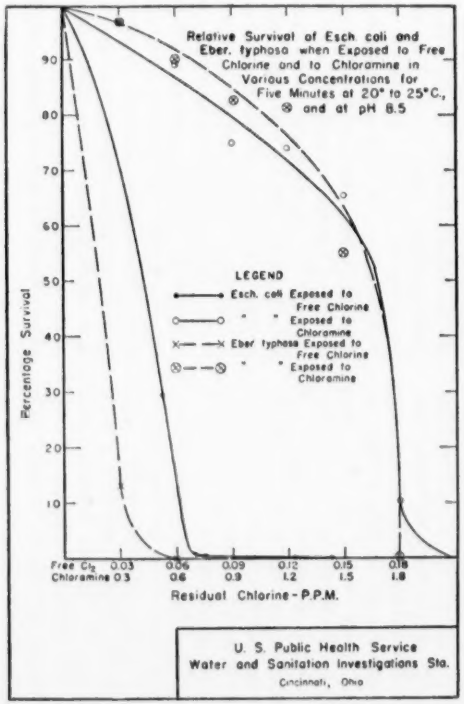
Relative Survival of Esch. coli and Eber. typhosa when Exposed to Free Chlorine and to Chloramine in Various Concentrations for Five Minutes at 20° to 25°C., ⊗ and at pH 8.5
LEGEND
Esch. coli Exposed to Free Chlorine
" " Exposed to Chloramine
Eber typhosa Exposed to Free Chlorine
" " Exposed to Chloramine
Percentage Survival
Free Cl2 0.03 0.06 0.09 0.12 0.15 0.18
Chloramine 0.3 0.6 0.9 1.2 1.5 1.8
Residual Chlorine - P.P.M.
U. S. Public Health Service
Water and Sanitation Investigations Sta.
Cincinnati, Ohio

FIG. 4

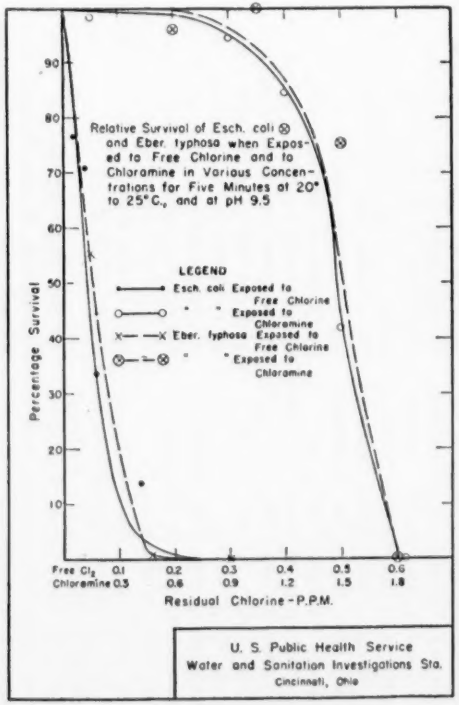
Relative Survival of Esch. coli ⊗ and Eber. typhosa when Exposed to Free Chlorine and to Chloramine in Various Concentrations for Five Minutes at 20° to 25°C., and at pH 9.5
LEGEND
Esch. coli Exposed to Free Chlorine
" " Exposed to Chloramine
Eber. typhosa Exposed to Free Chlorine
" " Exposed to Chloramine
Percentage Survival
Free Cl2 0.1 0.2 0.3 0.4 0.5 0.6
Chloramine 0.3 0.6 0.9 1.2 1.5 1.8
Residual Chlorine - P.P.M.
U. S. Public Health Service
Water and Sanitation Investigations Sta.
Cincinnati, Ohio

FIG. 5

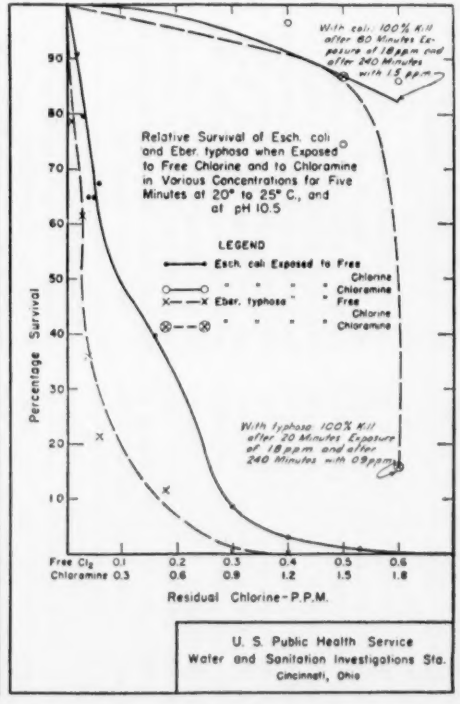
With coli 100% Kill after 60 Minutes Exposure of 1.8 p.p.m. and after 240 Minutes with 1.5 p.p.m.
Relative Survival of Esch. coli ○ and Eber. typhosa when Exposed to Free Chlorine and to Chloramine in Various Concentrations for Five Minutes at 20° to 25° C., and at pH 10.5
LEGEND
Esch. coli Exposed to Free Chlorine
" " " Chloramine
Eber. typhosa " " Free Chlorine
" " " Chloramine
With typhosa 100% Kill after 20 Minutes Exposure of 1.8 p.p.m. and after 240 Minutes with 0.9 p.p.m.
Percentage Survival
Free Cl2 0.1 0.2 0.3 0.4 0.5 0.6
Chloramine 0.3 0.6 0.9 1.2 1.5 1.8
Residual Chlorine - P.P.M.
U. S. Public Health Service
Water and Sanitation Investigations Sta.
Cincinnati, Ohio

FIG. 6

The Bacteriological Analysis of Water. E. WINDLE TAYLOR. Wtr. & Wtr. Eng. (Br.) **47**: 396 (Sept. '44). During past 40 yr. or more bact. methods employed to measure poln. and establish purity, while chem. anal. has taken on new importance in control of chem. treatment of water. Bacteriology can help water engr: (1) in opening new source of supply; (2) in indicating scope and extent of purif. necessary to render water safe to drink; (3) in making sure that eff. of operation maintd. at each stage of purif.; and (4) in establishing safety of finished water. Importance of correct method of collection of samples to be emphasized. Analyst entirely reliant on sampling being carried out properly. Most straightforward method of sampling is from tap. In rivers, streams, reservoirs, cisterns, etc., sometimes difficult to obtain representative sample. Bacteriologist has 3 groups of tests available: (1) total bacteria present, (2) examn. for specific disease-producing bacteria and (3) examn. for bacteria indicative of sewage poln. Three types of colony count in general use: (1) no. of bacteria growing on agar or gelatine media after 3 days at 22°C.; (2) no. growing on agar after 24 hr. at 37°C.; and (3) continuation of second count for period of 24 hr. Tests for specific intestinal organisms producing cholera, typhoid and para-typhoid fevers not employed as routine tests. Above are examples of "shutting stable door after steed is stolen." Necessary to search for bacteria indicative of poln. because they are found in excrements of man and animals. Three main bacterial types utilized in this way: (1) fecal streptococcus. Closely related to germs causing tonsilitis, scarlet fever, puerperal fever and blood poisoning. Growing in favor as critical indicator in purif. and anal. of swimming bath water. (2) *Clostridium welchii* causes gas gangrene in wounds and is widely situated in cultivated soil. Of particular value in examn. of well supplies. (3) Coliform group, comprises several species of bacteria closely allied to typhoid and dysentery bacteria. Enumeration of these organisms by far most delicate test for purity available. Ministry of Health in Rpt. 71 on "Bacteriological Examination of Water Supplies," have advocated setting up of 5 tubes at each vol., but in case of finished waters 100-ml. vol. subdivided into one 50-ml. and five 10-ml. portions. After inoculation into MacConkey broth, tubes incubated at 37°C. and examd. for acid and gas after 24 and 48 hr. If pos. reaction obtained, necessary to confirm whether due to *Esch. coli*. Older method, known as plating test, consists in isolation of organism in pure culture and subjecting to series of identification tests, procedure taking any time up to 4 days; second method depends on fact that fecal coli capable of living at 44°C., while most other members of group fail to grow at this temp. What interpretation is engr. to put on these findings? Fecal coli prime indication of sewage poln. Non-fecal coliform organisms, in absence of fecal coli, can be ignored until final sterilization process reached. In underground supplies presence of non-fecal types may be of importance. Similar conclusions can be applied to results of coliform test from mains and consumers' premises. To achieve consistency of results by different analysts standardization of sampling and technic with close attention to detail essential. Rpt. 71 of Ministry of Health has gone long way to provide such uniform procedure. With regard to scope of bact. examn. have more frequent samples but less complete anal. each time. Magnitude of causes of epidemics has sometimes remained undetected for some time. Only by frequent sampling that such tragedies could be detected early and so averted. Full anal. should be reserved for new and uncharted supplies. For water passing into supply, coliform test and plate count at 37°C. should be all that is necessary. Aim should be to draw samples at least 5 times a week.—*H. E. Babbitt.*

New Observations on Micro-organism Damage in Water Works. LEO MINDER. Schweiz. Ver. Gas-u. Wasserfach. Monats-Bull. (Swiss) **23**: 146, 182, 213, 241, 260 ('43). Review of cases of damage to water systems by bact. growth. *Leptothrix ochracea* can completely fill up well water system (Ossingen) if proper nutritional conditions established. Drainage from fodder silos especially suited if it penetrates soil near water source. Change in condition of ground water can be brought about by infiltration of river water of low oxygen content after artificial rise in river level. In one case (Wettingen) described, subsequent efforts to aerate water led to extensive growth of zooglea, forming dense slime flocculating all over water system, caused by cocci as well as bacteria. Chlorination cured situation reasonably well. Same water works later on troubled by increased Mn content of water causing pptn. under

influence of bacteria. For proper control of biol. conditions, necessary to keep available oxygen within limits, only 1 ml./l. water added. Water works Aue (Baden) had similar set of conditions all at same time: soln. of Fe wherever O content zero, mass growth of slime formers, together with Mn pptn. Definite attack of pipelines frequently caused by growth of iron bacteria, *Gallionella ferruginea;* it forms rust warts inside piping. This attack appears especially if Fe content of water low; exact conditions promoting its formation not known; however, forms generally wherever bare iron not protected by pptd. lime-rust layer.—*C.A.*

A Practical Study of Lauryl Sulfate Tryptose Broth for Detection of the Presence of Coliform Organisms in Water. MAC H. MCCRADY. Am. J. Pub. Health. **33**: 1199 (Oct. '43). Author describes study carried on by 17 state, provincial, county, city and univ. labs. in U.S. and Can. to det. utility of lauryl sulfate tryptose broth for detection of presence of coliform organisms in water. Total of 605 samples from which primary gas positives obtained examd. using L.S.T. broth as primary and secondary media for comparison with usual lactose broth in *Standard Methods* "completed test." Of these samples 526 also subjected to confirmed test procedure employing transfer from primary gas positives to B.G.B., and 318 examd. further by transfer from L.S.T. primary positives to B.G.B. It was found that use of L.S.T. broth as primary media reduced no. of primary positives about 13%. Further found that 77.5% of primary L.S.T. positives positive on secondary L.S.T. broth as against 75.1 on secondary lactose broth. In view of these figures, evident that L.S.T. broth cannot be employed as presumptive media without confirmation. They also indicate that L.S.T. broth superior to lactose broth as culture media for this work. In reviewing results taking into consideration type of water tested, however, evident that superiority of L.S.T. broth less marked for finished waters than it is for other types of waters such as raw, unfinished, swimming pool and well and spring water samples. More work on this type of sample recommended. Further observed that use of B.G.B. for confirmation yielded about as many positives as did completed test using either lactose broth or L.S.T. broth, but that transfers from L.S.T. primary broths yielded about 3.8% more positives than transfers from lactose broth.—*P.H.E.A.*

***Clostridium perfringens* as an Indicator of the Purity of Water.** ERNESTO DI LEO. Anales soc. cient. argentina. (Sp.) **136**: 68: 140 ('43). Discovery, taxonomy and characteristics of *Clostridium perfringens* and various methods of identification by culture discussed. Tables presented of results of examn. of series of waters, including natural surface and well waters, city water supplies and sewage in various stages of treatment. Counts presented of aerobic blood-temp. organisms, coliform organisms and *Clostridium perfringens* by methods of Wilson and Blair (J. Path. Bact. **24**: 111 ('23)) which use medium contg. sulfite and litmus milk agar. Wilson-Blair method includes step by which vegetative phases of all organisms are killed and only those spores that grow in anaerobic conditions develop. Tests such as formation of PbS that show formation of sulfides from sulfite are pos. for presence of *Clostridium perfringens.* This method preferred because presence of vegetative and spore forms of *Clostridium perfringens* detd. separately. Value of test is in that finding of spores gives warning of presence of distant source of contamn. that although *Esch. coli* may be absent in one sample it may appear in others. —*C.A.*

The Bactericidal and Bacteriostatic Action of Crystal Violet. C. E. HOFFMANN & O. RAHN. J. Bact. **47**: 2: 177 (Feb. '44). Two explanations of antiseptic action of dyes on bacteria given: (1) they poise medium at potential unfavorable for growth, and (2) they combine chemically with constituents of bact. cell. Evidence given here that both actions occur. Above certain concn., crystal violet purely and irreversibly bactericidal; death-rate varies with concn. ($n = 0.86$), unaffected by size of inoculum, and little affected by pH; young cells more susceptible than old. In lower concn. initial fall in viable count, rate of which is independent of dye concn. in this lower range, succeeded by multiplication: length of this lag phase varies with dye concn., varies inversely with size of inoculum, shorter when inoculum consists of young cells, and prolonged by raised oxygen concn. or increasing pH. [Former type of effect shown in expts. with highly susceptible organism, *Streptococcus lactis,* and latter with highly resistant one, *Esch. coli.* Stated in text but not evident in any figure, that *Streptococcus lactis* will eventually multiply in 1 ppm. of crystal violet, but it does not appear to have been shown that any concn.

of dye has first type of effect—viz., progressive and uninterrupted bactericidal action ending in extinction—on *Esch. coli.*]—*B.H.*

A Simple Method for Preservation and Transmission of Samples of Water Required for Bacteriological Analysis. W. STEUER. Arch. f. Hyg. u. Bakt. (Ger.) **130**: 3/4: 138 ('43). Difficulties have arisen over rapid transmission of samples of water from Eastern Front. Samples, un-iced and arriving at their destination several days after collection, have little value for assessment of purity. Method described by which bacteria in water sample maintd. at their initial concn. so that examn. can be carried out several days after collection. Briefly, procedure consists of absorption of water on filter paper and storing in air-tight, water-tight cellophane envelopes. For total colony counts filter paper about 10 cm. in diam. taken and one-quarter cut away. Paper then folded into cone and inoculated with ½–1 ml. of sample. Cone placed in sterile cellophane envelope and opening sealed with adhesive tape. For coliform count, larger filter papers and envelopes employed, so that as much as 10, 50 or even 100 ml. of water sample may be accommodated. Filter paper first placed in envelope, which has small openings at top and bottom. Water introduced by syringe or pipette through upper hole and allowed to flow on filter paper, where bacteria held up and excess water passes through and out of hole in bottom of envelope. Holes afterwards sealed with tape. Envelopes enclosed in grease-proof paper and packed in wooden box ready for transmission. Details given of filter paper and cellophane employed successfully in these operations. At lab. envelopes opened with sterile scissors and filter cones examd. One intended for total colony count opened out and placed in Petri dish and molten nutrient medium poured over it and thoroughly mixed. After incubation colonies counted in quarter plate not obscured by filter paper. Filter cone intended for coliform count placed in tube of nutrient broth, incubated at 46°C. and then plated out on Endo medium. Usually several cones examd., each contg. different vol. of water; in highly pold. waters coliform count may be estd. by direct plating as for total colony count. Author investigated several possible sources of error liable to arise in this method. Contamn. might occur at points of sealing; adhesive tape investigated and found free from bacteria. Slight loss of bacteria might occur by contact with and in condensation water flowing on to cellophane, but this not found sufficient to cause any appreciable loss of organisms. Actual alteration in nos. of bacteria on filter paper considered possibility, but shown that very little increase or decrease occurred. Some loss by bacteria percolating through paper and escaping in filtrate. Several expts. undertaken to test eff. of this preservation method. No significant change in total colony count on gelatine after filter cones inoculated and stored for as long as 12 days at temp. of 12–18°C. Pathogenic intestinal organisms survived on paper for 7 days and *Esch. coli* for 30 days. Paper sample stored in cellophane envelope compared with sample collected in usual glass bottle, latter being examd. at once; filter paper sample results same as bottle results up to 14 days after collection of sample. In addn., if bottle sample stored for few days at atm. temps., increase in counts, while results from filter paper samples remained const. at initial figures. [If this method found to be satisfactory it might be useful in tropical countries where transport slow and use of ice impracticable.]—*B.H.*

The Scientific Bases of Bacteriological Examination of Water. C. R. BAIER. Gas-u. Wasser. (Ger.) **83**: 329 ('40). Scientific bases of bact. examn. of water discussed. 2 chief methods for detg. bact. count are direct microscopic observation and detn. of number of colonies developing on nutrient agar or nutrient gelatin. Limitations and use of latter method, period of incubation and results obtained with agar and gelatin discussed. Because of small number of bacteria in water, necessary, when using direct microscopic examn., to conc. bacteria either by evapn. of sample or by pptn. with coagulant. By this method no distinction can be made between living and dead bacteria. Other methods used those in which number of bacteria of particular physiological group, such as coliform bacteria, detd. These methods may be divided into those in which nutrient medium specific for bacteria in question and those in which indicator added to medium in which several physiological groups will grow but in which only bacteria in question will produce typical color. Use of Endo medium and of Eijkman method as tests for coliform bacteria described. In detecting presence of sewage and in following course of self-purif. in streams,

concn. of suitable org. compd. in medium may be varied. With samples of water contg. sewage, number of bacteria increases much more rapidly on concd. medium than on dil. medium. As self-purif. of water proceeds, number of bacteria on concd. medium decreases more rapidly than on dil. medium. Tests for ammonia-producing, denitrifying, and nitrifying bacteria also used to follow self-purif. of water. More specific tests include those for typhoid bacteria and for *Serratia marcescens*. Metabolism of bacteria followed by observing biochem. changes in substrate. In modern methods usual to add substance to be decomposed to sample of water to be tested and, after incubation, to det. how much of substrate has been decomposed. In this way more natural conditions obtained. This type of method useful for observing self-purif. in streams and purif. of water in sand filters. Results of chem. anal. may be used to indicate bact. condition of water. For example, rapid decrease in content of D.O. in stream or in ground water indication of org. poln. Variations in contents of ammonia, nitrite, nitrate and carbon dioxide may also be indications of bact. activity.—*W.P.R.*

Research on Surface and Waste Waters by Means of the Bismuth Sulfite Medium of Wilson and Blair, in Relation to Typhoid Bacilli and Other Salmonellas. N. Černozubov, D. Filipovič & J. Stavel. Z. Hyg. Infektionskrank-. (Ger.) **125**: 5: 493 (Mar. 23, '44). Network of streams and open canals in and around Zagreb receives surface water and waste water from dwellings and public bldgs. Results of attempts to isolate intestinal pathogens from many points in these canals during '39–'40 recorded. Trials made of different methods of using Wilson and Blair's agar, including prelim. enrichment in fluid Wilson and Blair medium, sedimentation by various methods and poured-plate technic. Best results obtained, however, by surface inoculation of varying quants., from 0.2 to 2.0 ml., of water on Wilson and Blair's agar. Plates dried with lids partly raised, and, after incubation for 48–72 hr., suspected colonies picked to Russell's triple sugar medium. More than half canals found to be infected. Of 221 tests, 102 pos. for typhoid bacilli or *Salmonellas*, and isolations of 2 or more species of pathogen frequently made from same sample. Typhoid bacilli isolated 114 times (types I and II being separately recorded), *Salmonella schottmuelleri* 12 times, and *Salmonella newport*, *Salmonella brandenburg*, *Salmonella typhimurium* and *Salmonella derby* once each. 5 isolations of new Salmonella type, *Bact. zagreb*, made. Paper illustrated with photos of canals and maps showing exact sites of sampling. Isolations of typhoid bacilli made not only from canals receiving waste from hospitals and dwellings of known carriers, but also from areas where no carriers known, and from main canal at its point of entry into River Save 10 km. from Zagreb. Typhoid bacilli isolated twice from water involved in typhoid outbreaks. Method was to inoculate 4-ml. quants. on surface of 5 to 10 Wilson and Blair plates which were thoroughly dried before incubation.—*B.H.*

Experiences With the Bismuth Sulfite Media of Wilson and Blair in Examinations of Feces for *Eberthella typhosa* and Other *Salmonellas*. N. Černozubov, D. Filipovič, M. Hermann & J. Stavel. Z. Hyg. Infektionskrank-. (Ger.) **125**: 5: 510 (Mar. 23, '44). Description given of bismuth sulfite medium introduced by Wilson and Blair in '27, of modification made by these workers in '31, and that suggested by Wilson in '33. Authors found these media selective and satisfactory, but after many trials they devised their own (Zagreb) modification. Formula for this medium, which does not differ greatly from Wilson's '33 formula, as follows: (1) 20% dextrose in distd. water. Boil and restore to original vol. (2) Brilliant green Grübler in distd. water 1%. Shake till dissolved. (3) 20% Na_2HPO_4 (puriss. sicc.) in distd. water. Boil and restore to original vol. (4) 20% Na_2SO_3 puriss. sicc.) in distd. water. Boil and restore to original vol. (5) 8% $FeSO_4$ in distd. water. Do not boil. Add $2N/H_2SO_4$, 0.5 ml. to each 100 ml. (6) 12% bismuth ammonium citrate (Merck or Grübler). Do not boil. To 1 l. of sterile melted 3% agar add, in order: (1) 50 ml., (2) 5 ml., (3) 50 ml., (4) 100 ml., (5) 10 ml., (6) 50 ml. Mix well and pour plates at once. Known that typhoid colonies may fail to blacken if crowded, and that some strains do not blacken readily, if at all. Freshly prepd. plates alk. but, through loss of ammonia, pH falls and medium becomes green. Growth of pathogens then less satisfactory and colonial morphology less distinctive. Adequate buffering therefore necessary. Authors describe 7 colonial types of typhoid bacilli, varying in color from black to brown and green. They recommend that every type of colony which is at all suspicious should be picked for further study, irrespective of its

color. Direct plating on Endo's medium gave poor results. Relative success of other methods can be estd. from following table, which gives results of examn. of 2621 fecal specimens contg. typhoid bacilli and 384 specimens contg. other *Salmonellas*.

	Percentage Positive	
	Typhoid	*Salmonella*
1. Wilson and Blair (Zagreb)	81.0	44.5
2. Tetrathionate enrichment (Müller-Kauffmann) with plating on Endo	36.6	75.0
3. Tetrathionate enrichment (Müller-Kauffmann) with plating on Wilson and Blair	65.3	66.0
4. Combination of 1 and 3	98.3	73.9
5. Combination of 2 and 3	70.2	94.0
6. Combination of 1 and 2	88.9	90.0

Finally, authors tested their own medium in parallel with modification of Wilson's medium, described by him in '38, and found that latter less selective.—*B.H.*

Evaluation of Domestic Water Supplies on the Basis of Their Content of *Esch. coli*. J. PÁTER. Magyar Orvosi Arch. (Hungary) **43**: 337 ('42); Zentr. ges. Hyg. (Ger.) **51**: 190 ('43). In open wells temporary poln. by large numbers of coliform bacteria may occur; max. limit of 5 *Esch. coli* in 1 ml. of water for water supplies from such wells considered too strict. Recommended that in bact. examn. of domestic water supplies, besides accepted tests for *Esch. coli*, Darányi's test to det. thermal death-point should be used to distinguish between strains from cold-blooded and warm-blooded animals.—*W.P.R.*

Comparative Studies Concerning the Utilization of Ersatz Materials Instead of Meat or Meat Extracts for the Preparation of Bacterial Culture Media Used in Water Testing. H. BETHGE. Kleine Mitteilunge (Ger.) **18**: 184 ('42). Kuszynski's and Ferner's peptone free std. I and Mayer's probacit I bouillon tested on 99 samples of well, surface and drainage water and sewage showed practically identical numbers of bacteria on incubation. Number of other nutrient media showed poor correlation with beef extract.—*Willem Rudolfs.*

STREAM POLLUTION AND ITS CONTROL

Stream Sanitation. E. B. PHELPS. John Wiley & Sons, New York (1944). Book definitely not textbook nor is it for the novice. In spite of opening simple description of typical stream, in first chapter, occasional elementary discussions of units and few excellent easily understood analogies to illustrate complex biochem. reactions, author covers much highly complex and theoretical ground. Essentially review of biology and biochemistry as they apply to water supply and sanitation field. Avg. water works man, usually only casual student of these subjects, will have to dig deep to get full significance. Except for chapter on bact. poln., *Stream Sanitation* more applicable to problems associated with sewage disposal than with water supply. Book divided into 7 chapters, each covering rather broad field. First discusses characteristics of typical stream and touches briefly upon effects of many natural and man-made phenomena dealt with more fully in later chapters. Several digressions rather break up continuity of development of history of stream. Extended discussion of temp. changes and effects in reservoirs interposed at end of chapter. Chap. II covers biochemistry of growth and decay and deals with factors involved in continuous changes in org. and mineral matter as various elements go through their chain cycles. Chap. III deals with aerobic decompn., or oxidation. Included is review of development of tests for biochem. stability, from nitrogen tests of late 19th century, through relative stability test, to universally used B.O.D. test of today. Author shows similarity in biochem. reactions in rivers and in sewage treatment by means of sand filters, trickling filters and activated sludge plants. Chap. IV, pertaining to anaerobic decompn., deals primarily with digestion as it takes place in Imhoff tanks or digestion tanks, with discussion of benthal decompn. and its effects on overlying stream, based largely on work of Fair and Moore. In Chap. V, "The Oxygen Balance," Prof. Phelps draws together into one picture various processes at work which add to or deplete oxygen supply in stream. Application of math. formulas to predict stream conditions based primarily on well-known Ohio R. studies and of course

limited in its application by divergent conditions elsewhere. Chap. VI, on public health aspects, one of best chapters in book, deals with bact. poln. as distinguished from org. poln. "Streams that are studied from a general nuisance and oxygen balance point of view are so heavily polluted that they would never be considered suitable for domestic water supply, while streams fit for water supply have no oxygen balance problem." Admittedly rough approximations show criteria for raw water supply to be 500 times as stringent as criteria to prevent nuisance. While quant. expressions of bact. density, death rate, etc., necessarily approx. and based on data not applicable to many streams, chapter reviews well many factors affecting safety of stream, lake or bay for domestic water supply, bathing or shellfish. Final chapter on stream microbiology prepd. by James B. Lackey, Sr. Biologist, U.S.P.H.S. Contains several tables and illustrations and very brief review of types and densities of organisms frequently found in rivers and lakes, and discusses factors of importance affecting their presence. Too large a field to be covered in few pages. Environmental conditions vary widely within same stream and from one stream to another, with equally varied effects on plant and animal life. In general stream pop. dependent on amt. of food materials, temp., speed of current, amount of erosive material carried, age of water, contributed toxic substances and contributed oxygen-consuming substances. Author points out that one of difficulties in detg. effect of poln. on microscopic life in rivers is scarcity of virgin uncontamd. streams to show natural growth without poln. In this respect problem akin to increasing difficulty in hydrol. studies to find stream flow data not affected by control works of some kind. Author covers many controversial subjects and not all will agree with his conclusions nor have too much faith in some attempts to show stream conditions by math. formulations. He indicates frequently how diverse are conditions in rivers and impossibility of transposing data. Principal difficulty in stream poln. work is lack of adequate data and extensive surveys required to obtain them. Ohio R. studies, of course, outstanding, but except for these and much more limited investigations on Potomac R., New York Harbor and few others, very few data available. Prof. Phelps champions cause of cleaner rivers, bays and bathing beaches, and, in reviewing trend of conflicting uses states "with considerable assurance," in effect, that trend distinctly in direction of conservation of water resources for recreational uses. Trend also in direction of cleanliness and decency, for themselves, as against formerly abused privilege of sewage disposal by so-called "diln. process." Max. utilization of all stream assets essentially conservation to old-fashioned end of greatest good to greatest number. In field of sewage and waste disposal we utilize assets of oxygen balance and natural powers of stream to dissolve oxygen from air and, with aid of bact. and other life of streams, to oxidize and eventually dispose of org. poln. No more economic process of disposal. So economical is it in fact that this virtue has been its undoing. By overloading, we have too often broken down and rendered useless those very properties of stream upon which its power to dispose of org. wastes depends. Author's hope that in developing future sewage disposal works more consideration will be given to abilities and limitations of receiving stream, and to use to which water might be put in better and more pleasant community.—*R. Hazen.*

Permissible Pollution of Streams. GORDON C. LAIDLAW. Can. Engr.—Wtr. & Sew. **82**: 6: 21 (June '44). General discussion of poln. and natural purif. Pathogenic bacteria rapidly disappear from clean oxygenated water and chief problem, therefore, prevention of excessive org. matter contents and maint. of sufficient D.O. to oxidize org. matter. Evidence that oxidation of org. matter in water by bacteria occurs at appreciable rates only when conditions such that bacteria multiplying rapidly. Plankton, by utilizing bacteria as food, keep bact. pop. below possible max. concn. and thus permit active bact. multiplication to proceed. Anaerobic digestion occurs in sludge deposits but products require O for stabilization and evidence indicates that such anaerobic digestion does not reduce total O demand of stream. Main sources of O are diln. water, atm., and photosynthesis. Temporary increase in bact. pop. on diln. with oxygenated water results in increased rate of oxidation. Insufficient O may result in longer survival of pathogenic bacteria, tastes and odors, and death of fresh water life, including fish. Antiseptic substances which inhibit fresh water organisms interfere with oxidation of poln. In Great Britain, streams of same general type and std. for sewage effluents such as that of Royal Com. on Sewage and Sewage Disposal ('12), based on maint. of 5-day

B.O.D. no greater than 4 ppm. immediately below point of poln., covers all conditions fairly well. On this continent, conditions vary widely and usual practice is to classify streams or sections of stream according to local or downstream uses. Oregon State Sanitary Authority stds. quoted as example of this practice. Other authorities treat each source of poln. as separate problem. Combination of these methods of attack probably answer to problem.—*R. E. Thompson.*

War Production Board—Office of War Utilities

Administrative Letter to All Utilities—July 25, 1945

REVISED PRIORITIES SYSTEM

This letter is to call your attention to Priorities Regulation 29, issued by the War Production Board on June 30, 1945. This regulation describes the transition from the present priorities system of AA preference ratings and allotment symbols to one consisting of only two preference ratings: (1) the present AAA rating and (2) an MM rating reserved for military procurement.

On Jan. 1, 1946, the preference ratings and allotment symbols assigned by utility orders for maintenance, repair and operating supplies and those specifically assigned for major construction on Form WPB-2774 will become invalid along with all other AA preference ratings and allotments issued by the War Production Board. Up to that time the AA rating system will remain in effect but only in so far as deliveries to be made in 1945 are concerned. After October 1 all outstanding AA ratings become invalid on orders calling for delivery in 1946; however, up to that time, such ratings may be used to obtain a place on 1946 delivery schedules for products which require long production cycles.

Under the recent amendments of the utility orders it has been possible for utilities to undertake expansions of facilities, except for the construction of buildings, without specific authority from the Office of War Utilities. Some difficulties are being encountered, however, in obtaining material and equipment to carry out much of this desirable construction without preference rating and allotment assistance. The steps announced in Priorities Regulation 29 will soon abolish the advantages of preference ratings and allotment symbols, particularly on longer lead-time items and will thus permit utilities to profit more fully from the relaxations in the controls of construction which OWU adopted in the early part of June.

Very truly yours,

(signed) EDWARD FALCK
Director
Office of War Utilities